

Assessing Landslide Hazards Before and During an Event

Thomas Stanley, Universities Space Research Association, Goddard Earth Sciences Technology and Research, NASA Goddard Space Flight Center

August 26, 2021



Training Outline

Assessing Pre- and Post-Storm Impacts

August 18, 2021



<https://phys.org/news/2019-12-philippines-homes.html>

Assessing Sea Level Rise at the Regional to Local Scale

August 24, 2021



https://e360.yale.edu/features/rising_waters_how_fast_and_how_far_will_sea_levels_rise

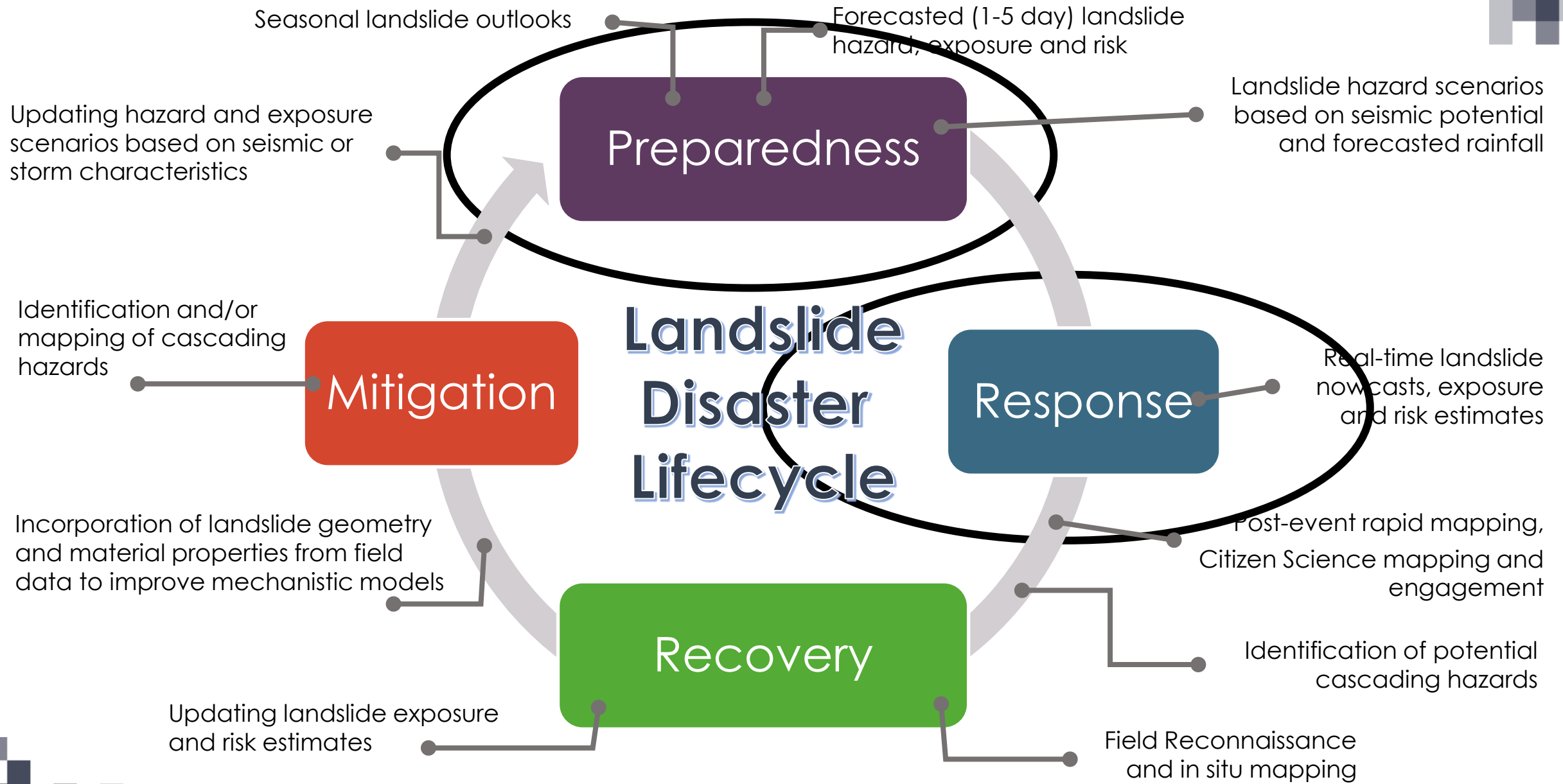
Assessing Landslide Hazards

August 26, 2021



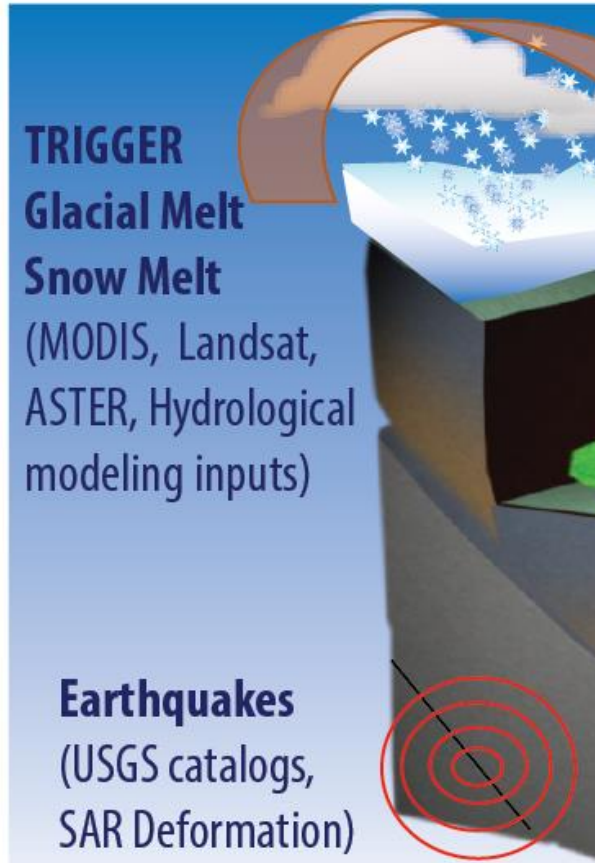
<https://ttweathercenter.com/severe-weather/landslides/>





Landslides are a major pr

And they have many causes.



earthquake.usgs.gov/earthquakes/eventpage/us6000eyfk/ground-failure/summary

Felt Report - Tell Us!

Did You Feel It?

ShakeMap

PAGER

Ground Failure

Technical

Origin

Moment Tensor

Waveforms

Download Event KML

View Nearby Seismicity

Earthquakes

Hazards

Data & Products

Learn

Monitoring

Research

Summary About

Landslides

Estimated Area Exposed to Hazard

Little or no landsliding is expected, but some landslides could have occurred in highly susceptible areas.

Estimated Population Exposure

The number of people living near areas that could have produced landslides in this earthquake is low, but landslide damage or fatalities are still possible in highly susceptible areas. This is not a direct estimate of landslide fatalities or losses.

VIEW LANDSLIDES MAP

Liquefaction

Estimated Area Exposed to Hazard

Little or no liquefaction is expected, but some liquefaction could have occurred in highly susceptible areas.

Estimated Population Exposure

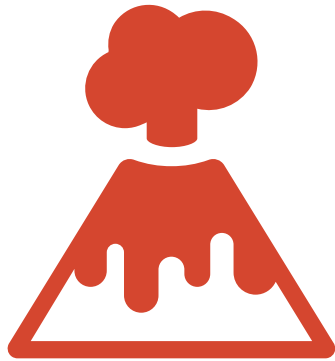
The number of people living near areas that could have produced liquefaction in this earthquake is low, but liquefaction damage or fatalities are still possible in highly susceptible areas. This is not a direct estimate of liquefaction fatalities or losses.

VIEW LIQUEFACTION MAP



Some small island nations are highly exposed to landslides...

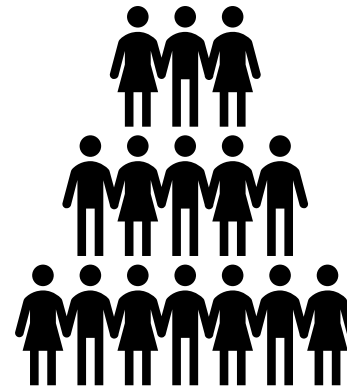
Due to a common combination of factors:



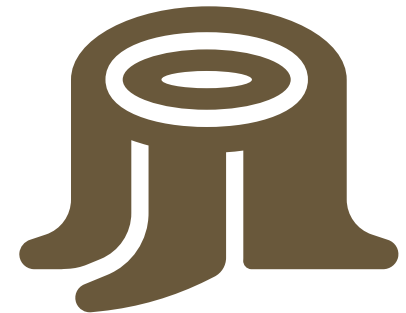
Volcanic Soils
and Steep Slopes



Intense
Tropical
Cyclones

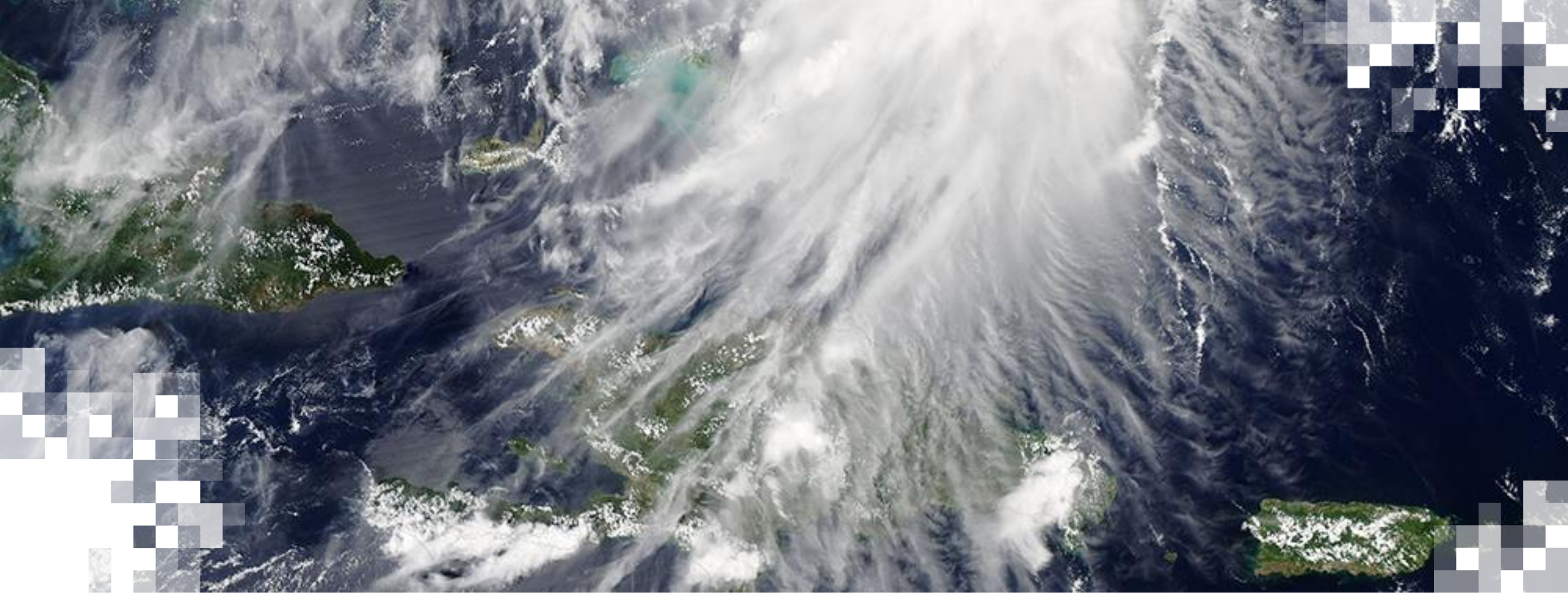


Dense
Population



Deforestation

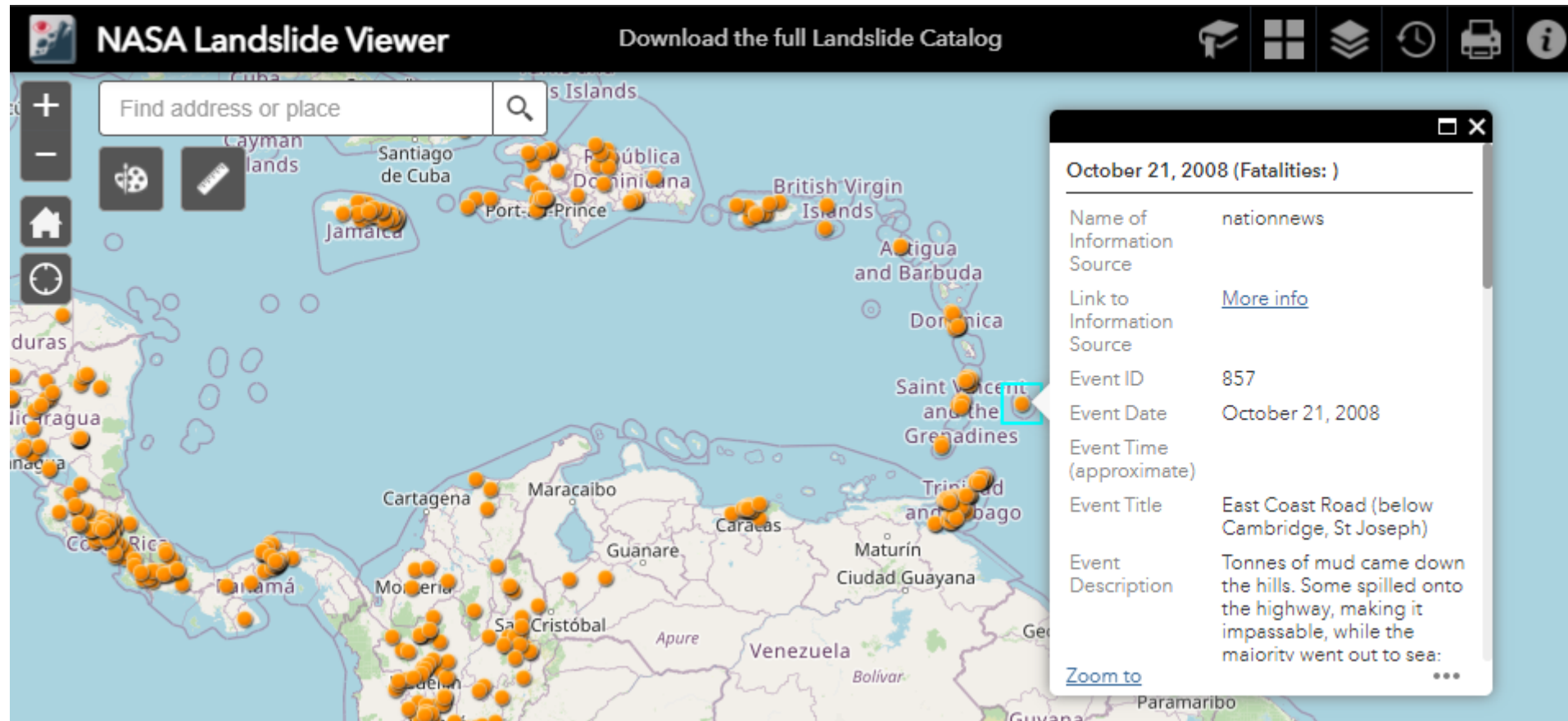




Some Resources for Assessing Landslide Hazard
Before an Event

Global Landslide Catalog (GLC)

At Landslide Viewer (landslides.nasa.gov/viewer)



Global Landslide Catalog (GLC)

At Landslide Viewer (landslides.nasa.gov/viewer)

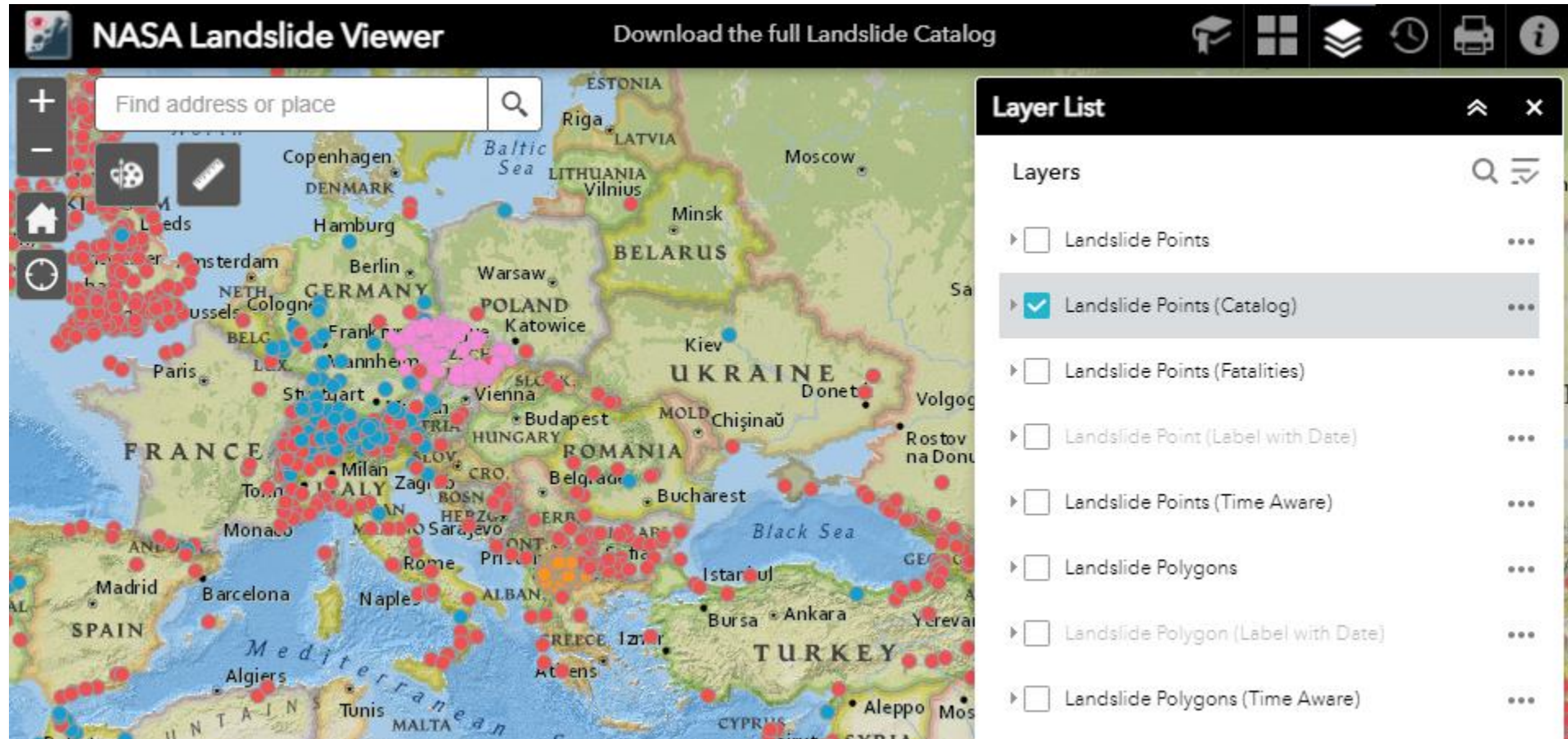
The screenshot shows the NASA Landslide Viewer interface. At the top, there's a header with the NASA logo, the text "NASA Landslide Viewer", and a link to "Download the full Landslide Catalog". Below the header is a search bar with the placeholder text "Find address or place". To the left of the search bar are navigation controls: a zoom in (+) and zoom out (-) button, a home button, and a refresh button. Below these are two icons: a globe and a ruler. The main map area shows a satellite view of a landscape with a yellow and orange highlighted area indicating a landslide. A detailed information panel is open over the map, displaying the following data:

December 14, 2016 (Fatalities: 0)	
Name of Information Source	The Sacramento Bee
Link to Information Source	More info
Event ID	10,230
Event Date	December 14, 2016
Event Time (approximate)	
Event Title	Highway 299 Rock slide North California
Event Description	A steep hillside 28 miles west of Weaverville slid onto Highway 299, dumping rocks as big as a small house and enough

At the bottom of the panel is a "Zoom to" button. To the right of the map is a "Basemap Gallery" with a grid of map styles: Dark Gray Canvas, Imagery (selected), Imagery with Labels, Light Gray Canvas, National Geographic, Oceans, OpenStreetMap, Streets, Terrain with Labels, and Topographic.

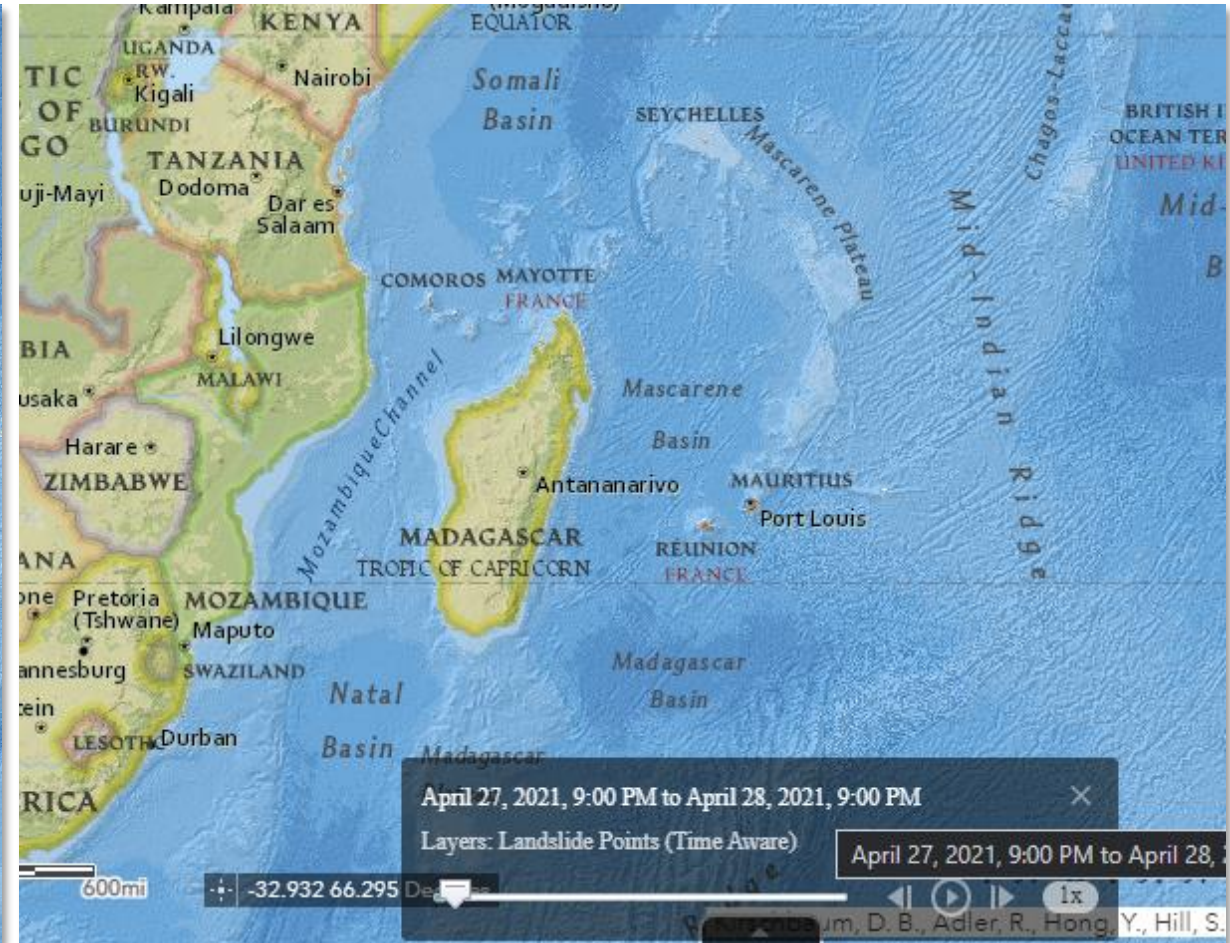
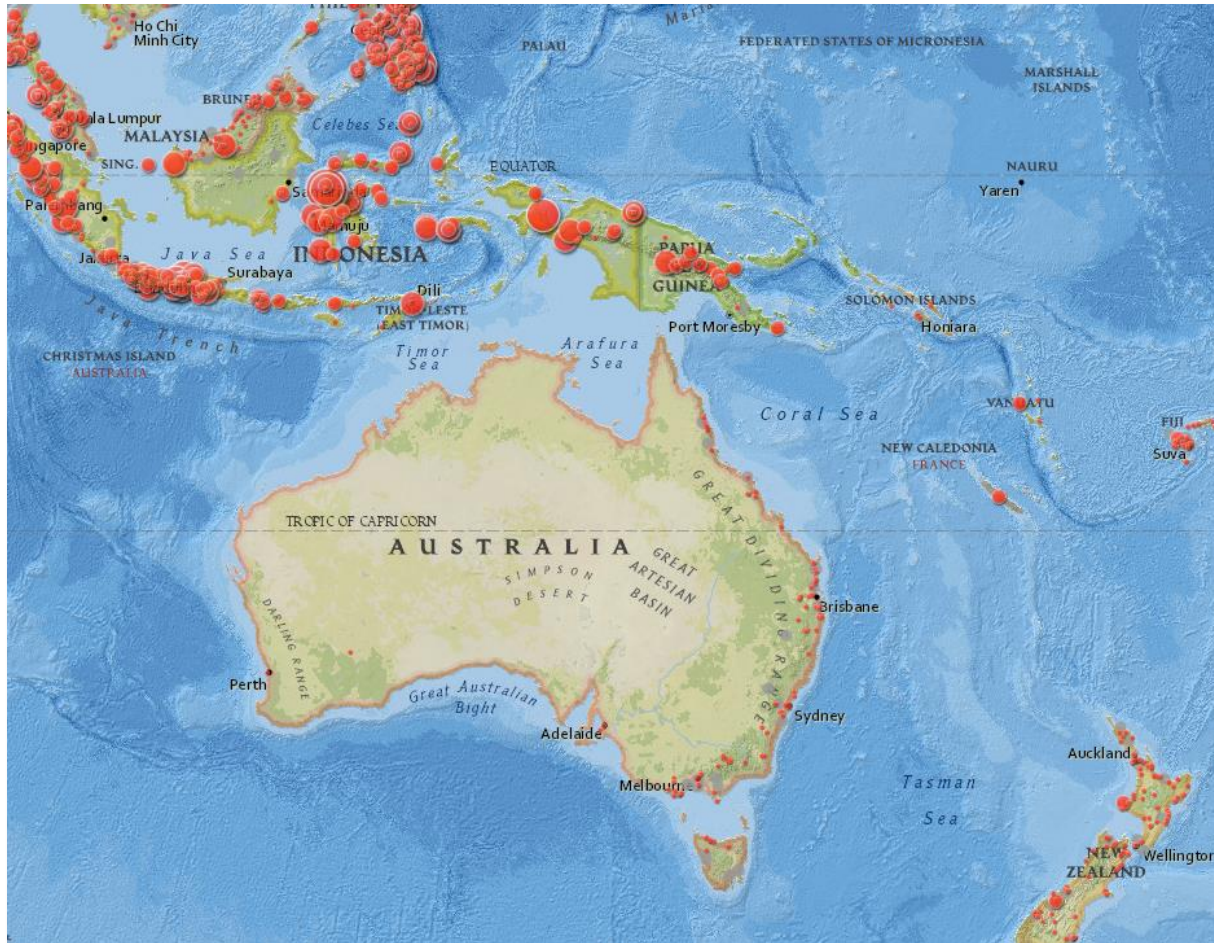
More from the Cooperative Open Online Landslide Repository (COOLR)

At Landslide Viewer (landslides.nasa.gov/viewer)



Fatalities and Time

At Landslide Viewer (landslides.nasa.gov/viewer)



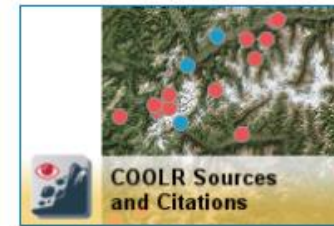
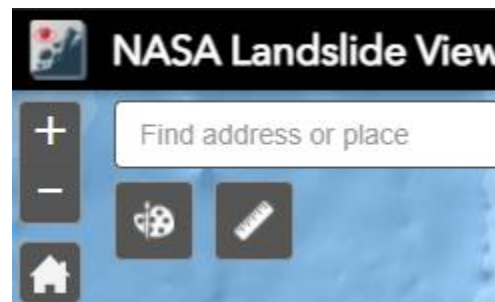
Download All the Data in C At Landslide Viewer ([landslides.](https://landslides.nasa.gov)

Global Landslide Catalog Downloadable Products

The Cooperative Open Online Landslide Repository (COOLR) is a worldwide database of landslide events from NASA, scientists, and citizen scientists. You can download the COOLR catalog as a file geodatabase (.gdb), shapefiles (.shp), or comma-separated values (.csv). Learn more about the data and citizen science at landslides.nasa.gov.

Tags

617 catalog coolr csv file
geodatabase glc global
landslide landslide inventory
nasa point polygon shapefile



COOLR Sources and Citations (CSV)

CSV

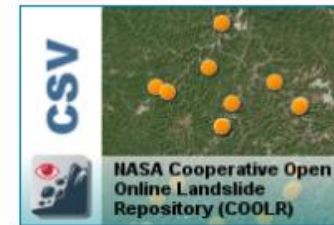
Important citation information about the landslide catalogs within the Cooperative Open Online Landslide Repository.



Global Gridded Landslide Inventory

CSV

Count of landslides mapped within each 1-km grid cell. This file contains most of the landslide inventories used for training version 2.0 of the global landslide nowcast, now under review at Frontiers in Earth Science.



NASA Global Landslide Catalog Points (CSV)

CSV

The NASA Cooperative Open Online Landslide Repository (COOLR) points, downloadable as a .csv file.



NASA Global Landslide Catalog Points (Shapefile)

Shapefile

The NASA Cooperative Open Online Landslide Repository (COOLR) points, downloadable as a .shp file.



NASA Global Landslide Catalog Polygons (CSV)

CSV

The NASA Cooperative Open Online Landslide Repository (COOLR) polygons, downloadable as a .csv file.



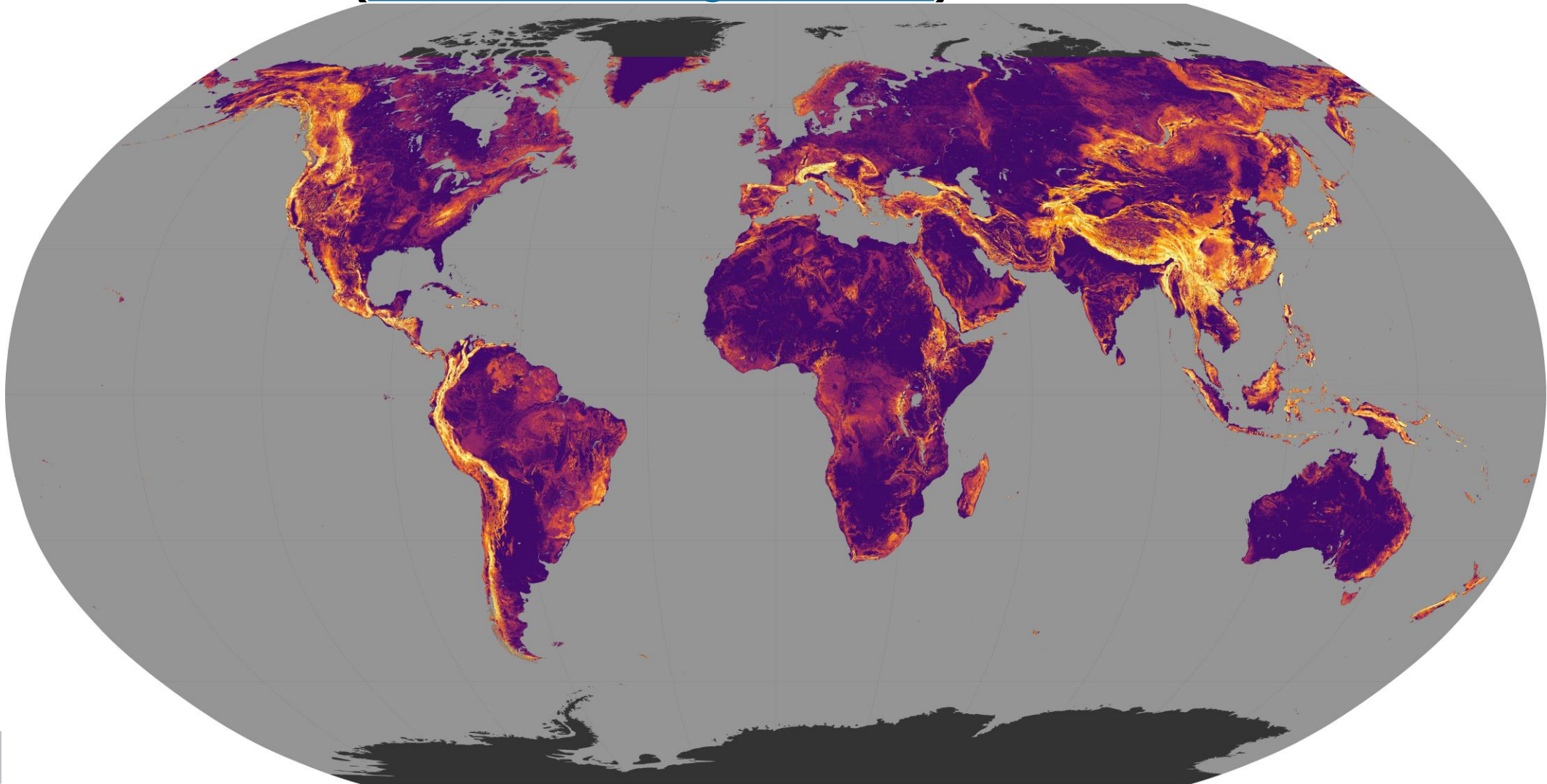
NASA Global Landslide Catalog Polygons (Shapefile)

Shapefile

The NASA Cooperative Open Online Landslide Repository (COOLR) polygons, downloadable as a .shp file.

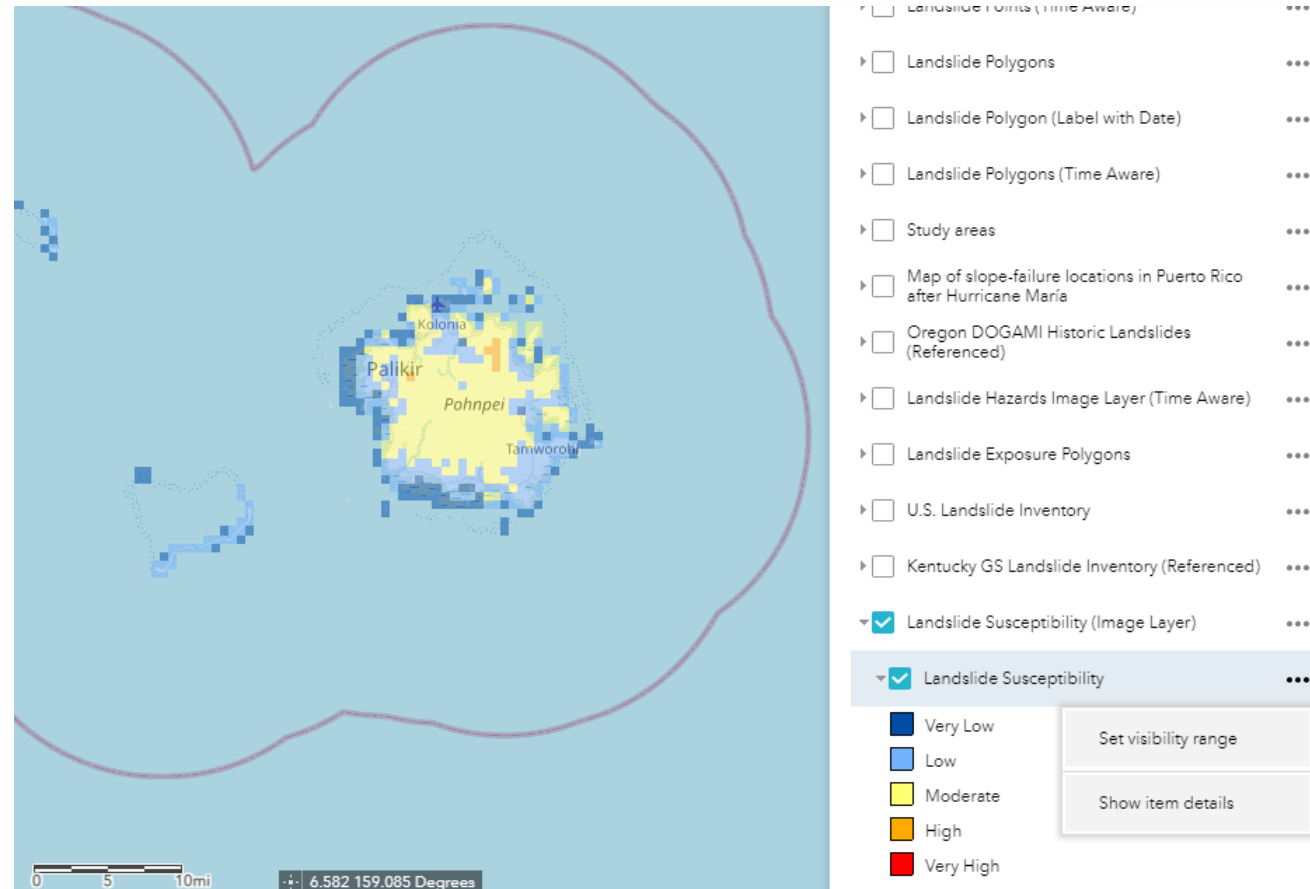
Global Landslide Susceptibility Map

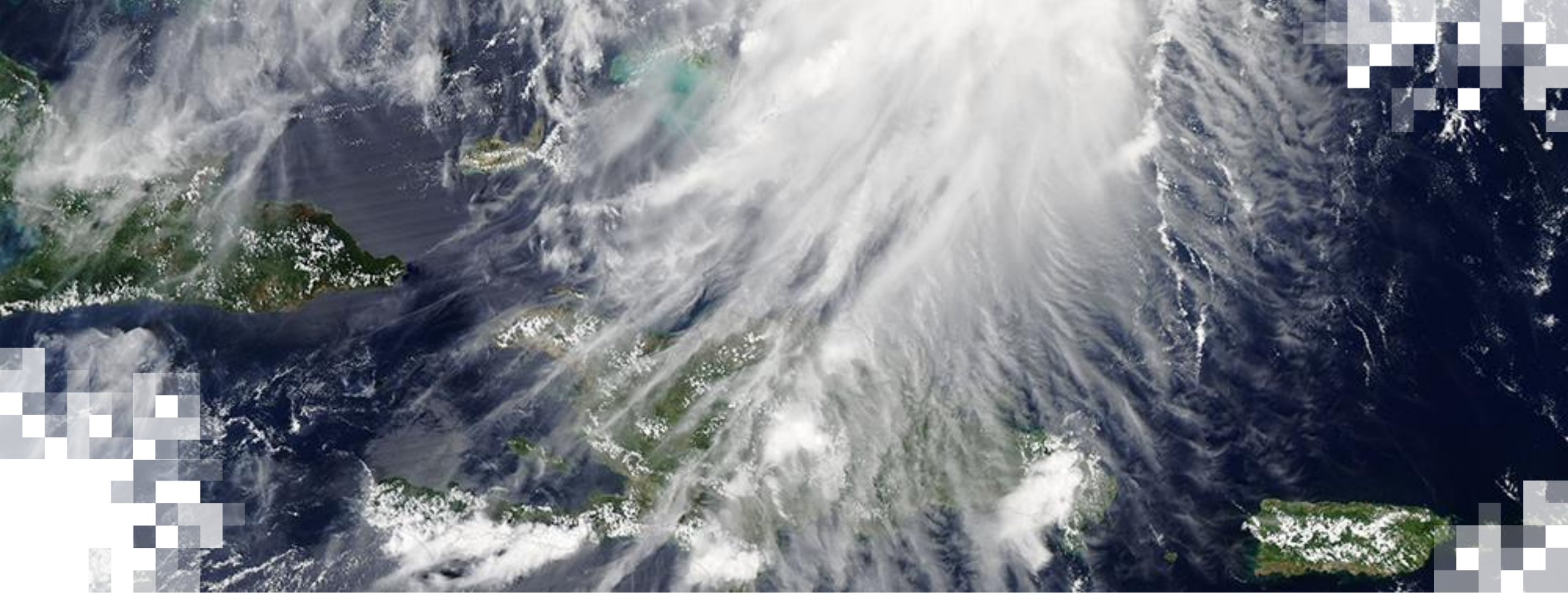
At Landslide Viewer (landslides.nasa.gov/viewer)



Global Landslide Susceptibility Map

At Landslide Viewer (landslides.nasa.gov/viewer)

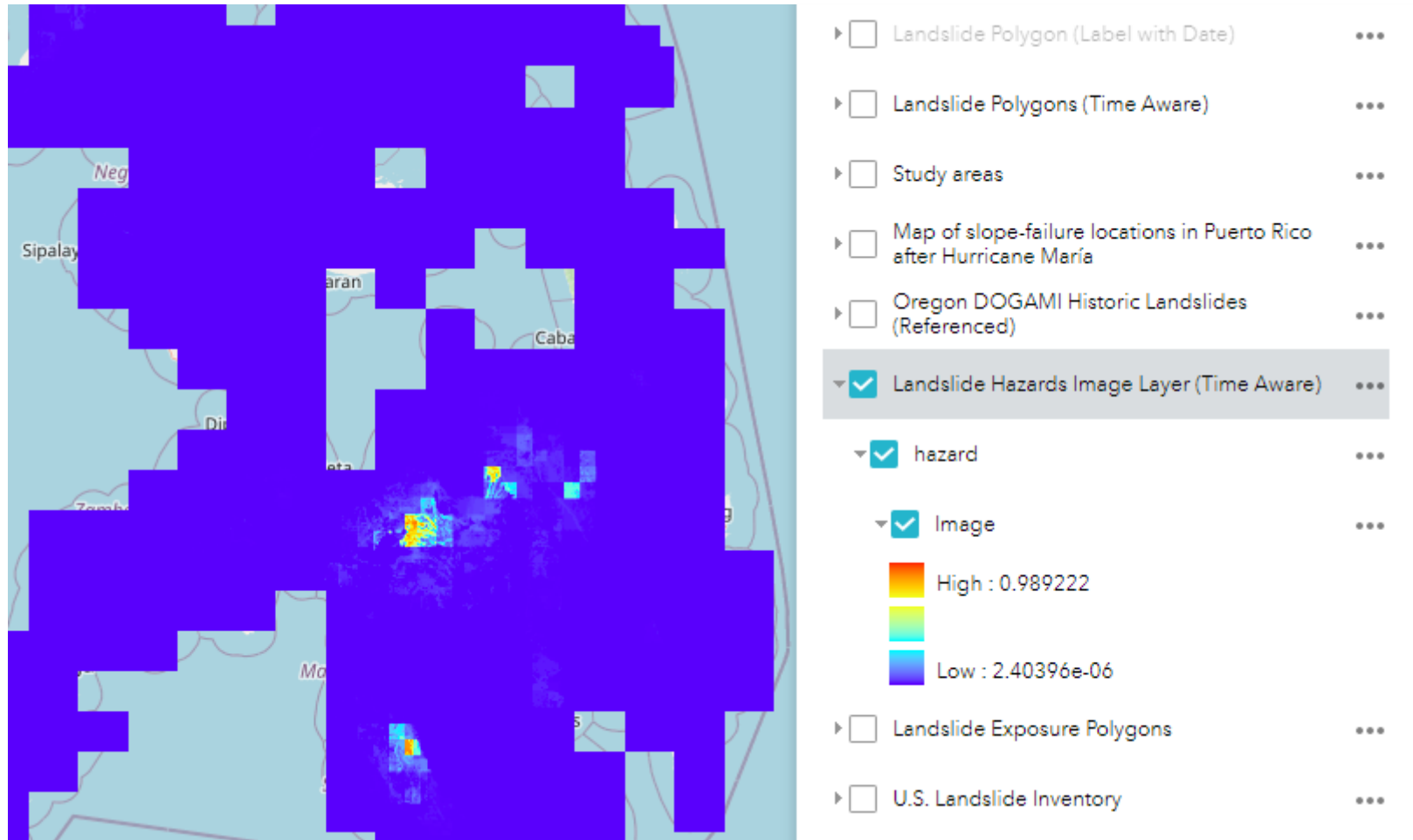




Some Resources for Assessing Landslide Hazard
During an Event

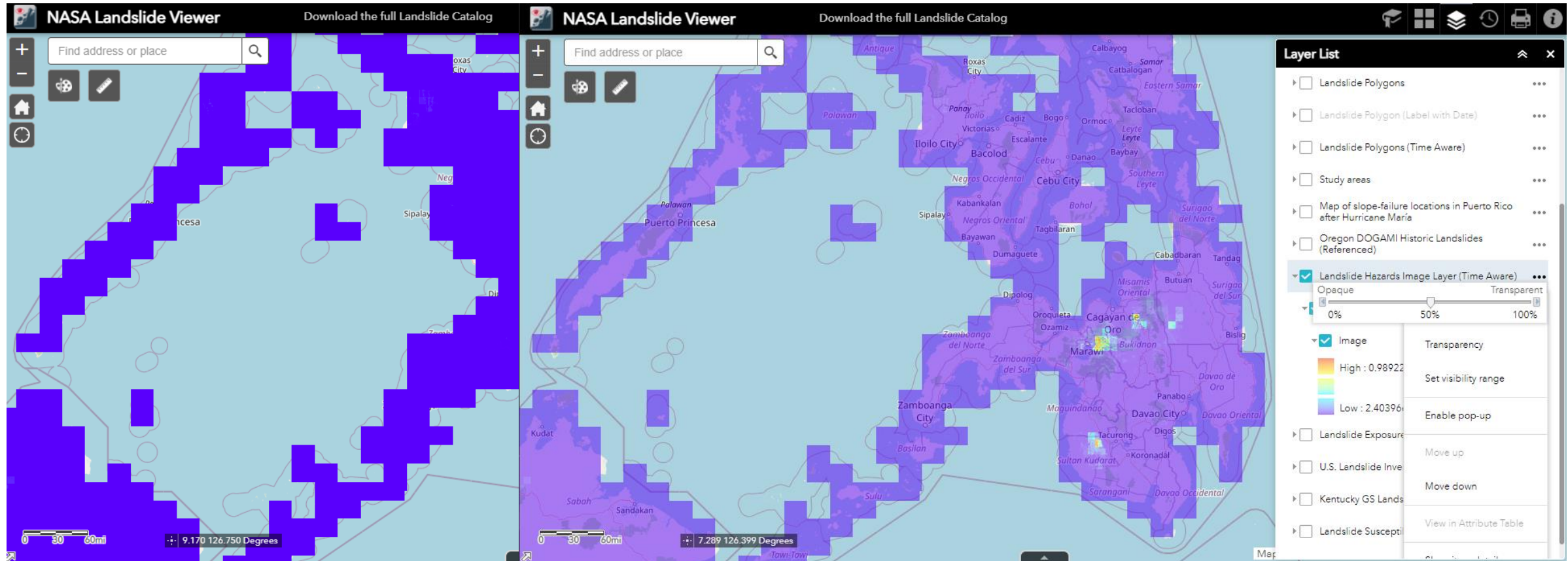
Global Landslide Nowcast

At Landslide Viewer (landslides.nasa.gov/viewer)



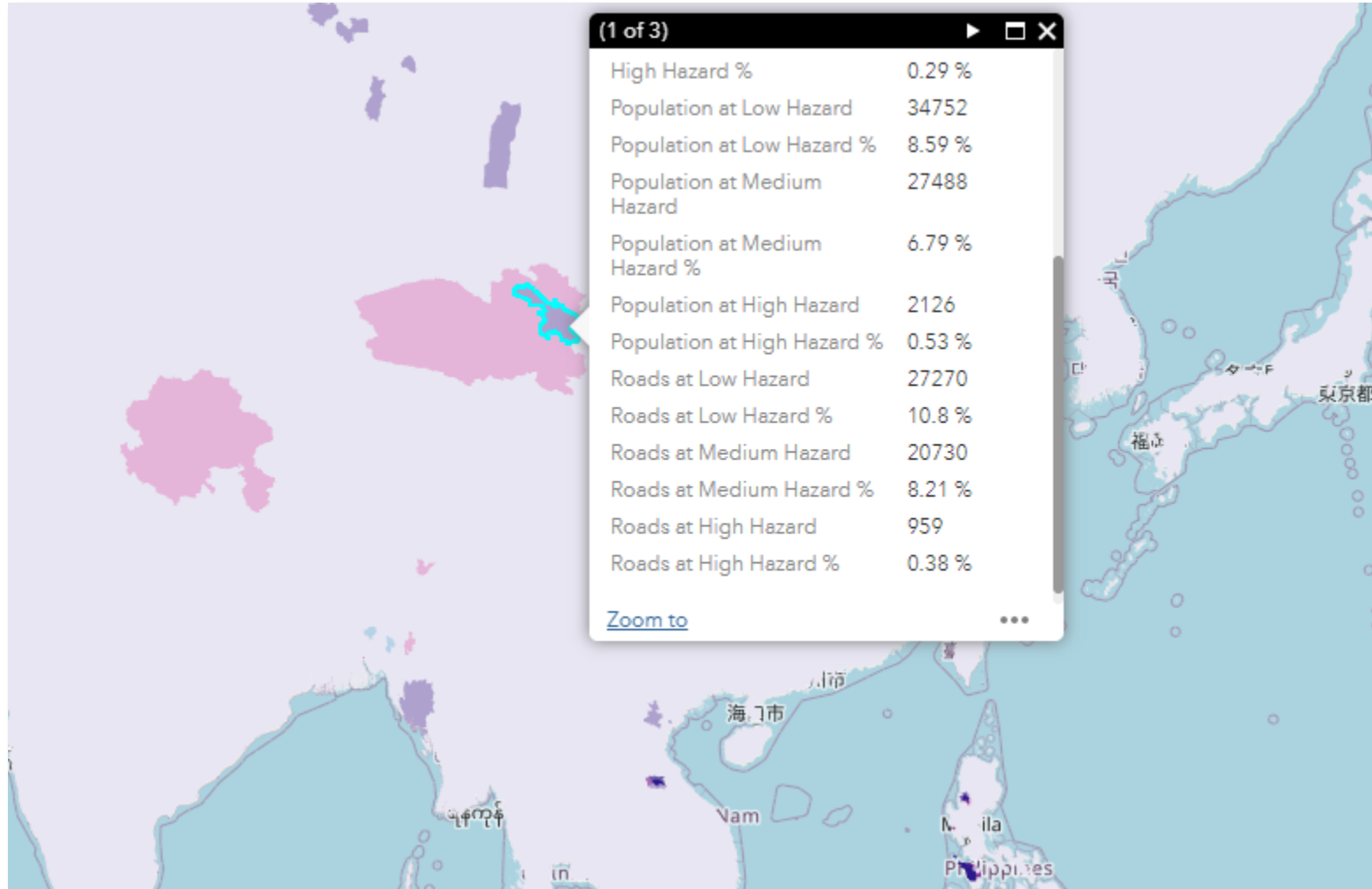
Global Landslide Nowcast

At Landslide Viewer (landslides.nasa.gov/viewer)



Exposed Population and Roads from the Global Landslide Nowcast

At Landslide Viewer (landslides.nasa.gov/viewer)



Exposed Population and Rockfall Hazard

Global Landslide Nowcast

At Landslide Viewer (landslides.nasa.gov)

maps.nccs.nasa.gov/download/landslides/nowcast/exposure/

Index of /download/landslides/nowcast/exposure/

Name	Last modified	Size	Description
Parent Directory		-	
admin2.zip	26-May-2021 10:06	325M	
csv/	23-Jul-2021 10:30	-	

Index of /download/landslides/nowcast/exposure/csv/

Name	Last modified	Size	Description
Parent Directory		-	
2021-04-11_1900.csv	05-May-2021 13:31	4.3M	
2021-04-14_0000.csv	05-May-2021 13:31	4.4M	
2021-04-26_1900.csv	05-May-2021 13:31	4.4M	
2021-04-27_0900.csv	05-May-2021 13:31	4.4M	
2021-05-03_0900.csv	05-May-2021 13:31	4.5M	
2021-05-03_1500.csv	05-May-2021 13:47	4.5M	
2021-05-04_0900.csv	14-May-2021 11:27	4.5M	
2021-05-12_0900.csv	14-May-2021 11:27	4.4M	
2021-05-12_1500.csv	14-May-2021 11:27	4.4M	
2021-05-13_1500.csv	14-May-2021 16:31	4.4M	
2021-05-13_2100.csv	14-May-2021 22:30	4.4M	
2021-05-14_0300.csv	15-May-2021 04:30	4.4M	
2021-05-14_0900.csv	15-May-2021 10:30	4.4M	
2021-05-14_1500.csv	15-May-2021 16:30	4.4M	
2021-05-14_2100.csv	15-May-2021 22:30	4.4M	
2021-05-15_0300.csv	16-May-2021 04:30	4.4M	
2021-05-15_0900.csv	16-May-2021 10:30	4.4M	
2021-05-15_1500.csv	16-May-2021 16:30	4.4M	
2021-05-15_2100.csv	16-May-2021 22:30	4.5M	
2021-05-16_0300.csv	17-May-2021 04:30	4.5M	
2021-05-16_0900.csv	17-May-2021 10:30	4.5M	

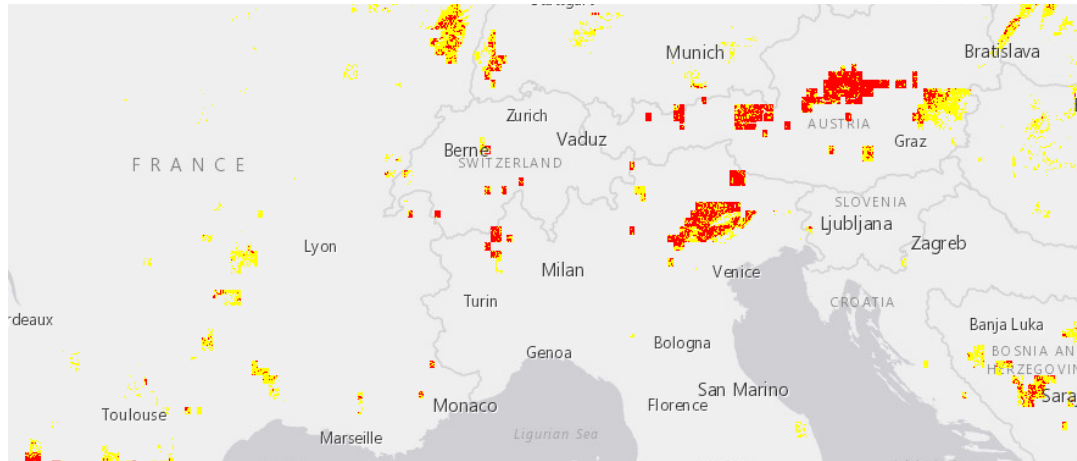
New Features in the Global Landslide Nowcast (LHASA 2.0)

- Probabilistic, rather than categorical outputs
 - Due to the use of machine learning
 - Incorporates soil moisture and snow mass
- Increased accuracy
- Exposure analysis
- However, version 1.1 is still published at <https://pmmmpublisher.pps.eosdis.nasa.gov/> and <https://gpm.nasa.gov/data/visualizations/precip-apps>.
- Both sites allow you to view the “classic” model output:

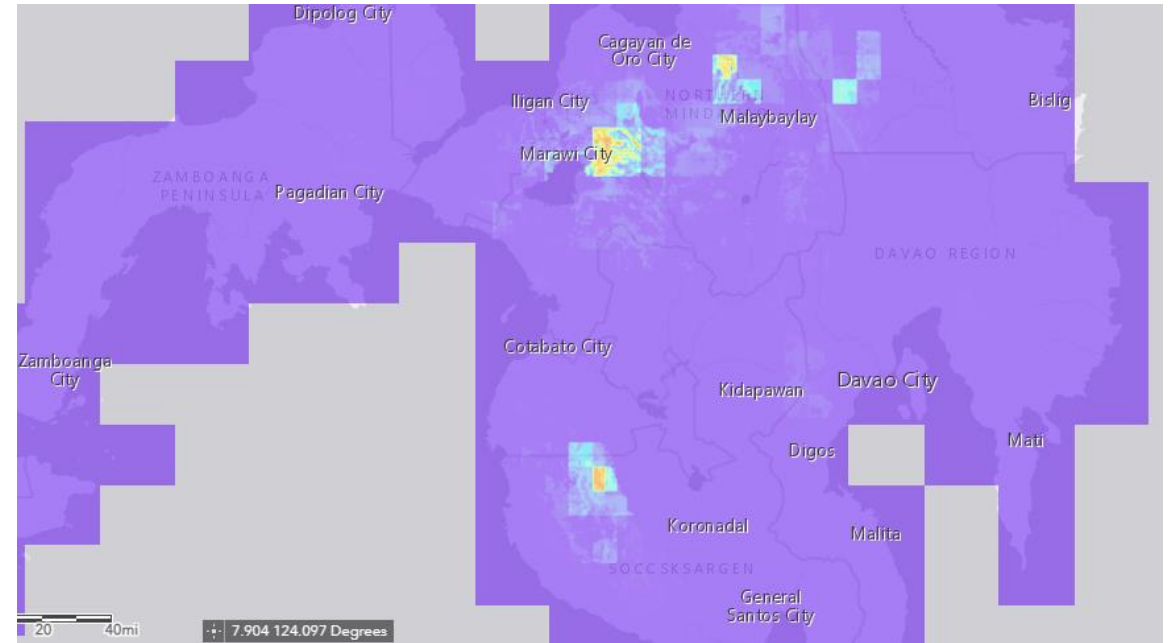


The Landslide Hazard Assessment for Situational Awareness (LHASA) Model

Version 1.1

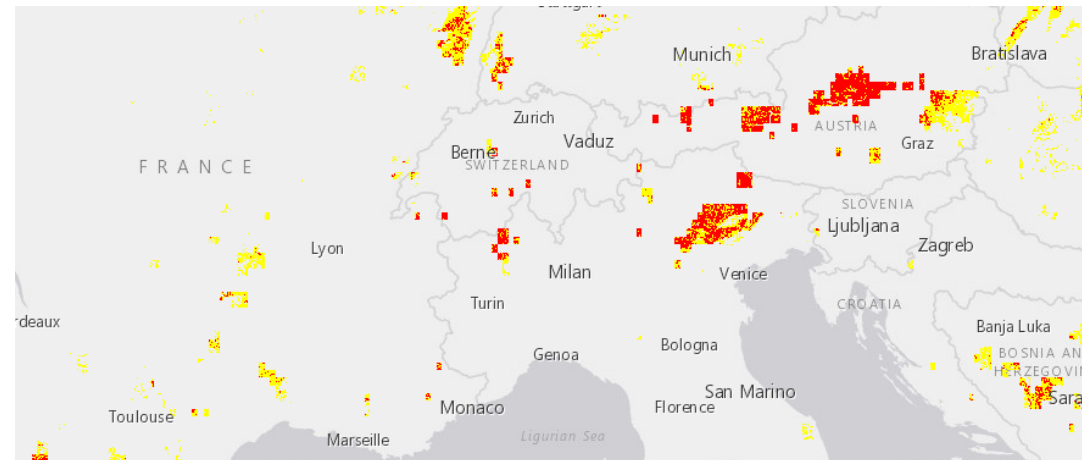
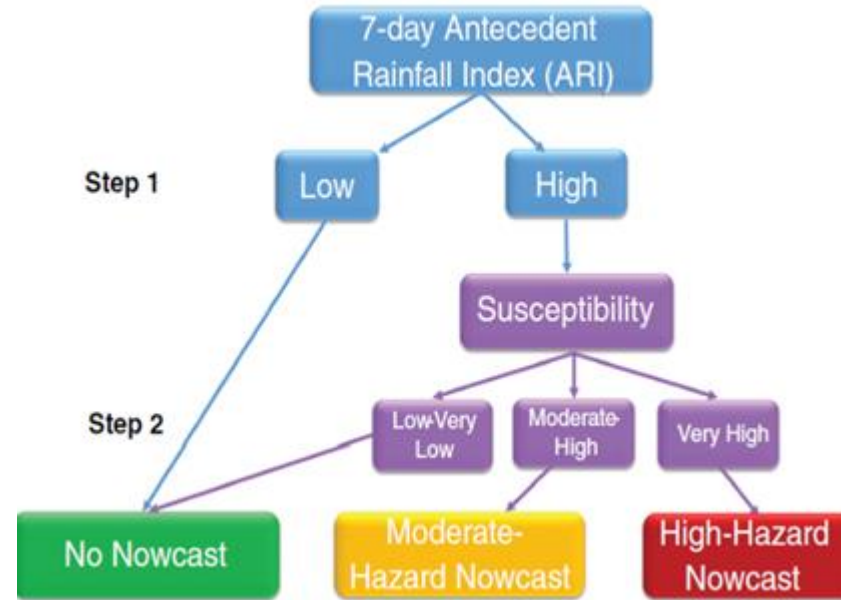
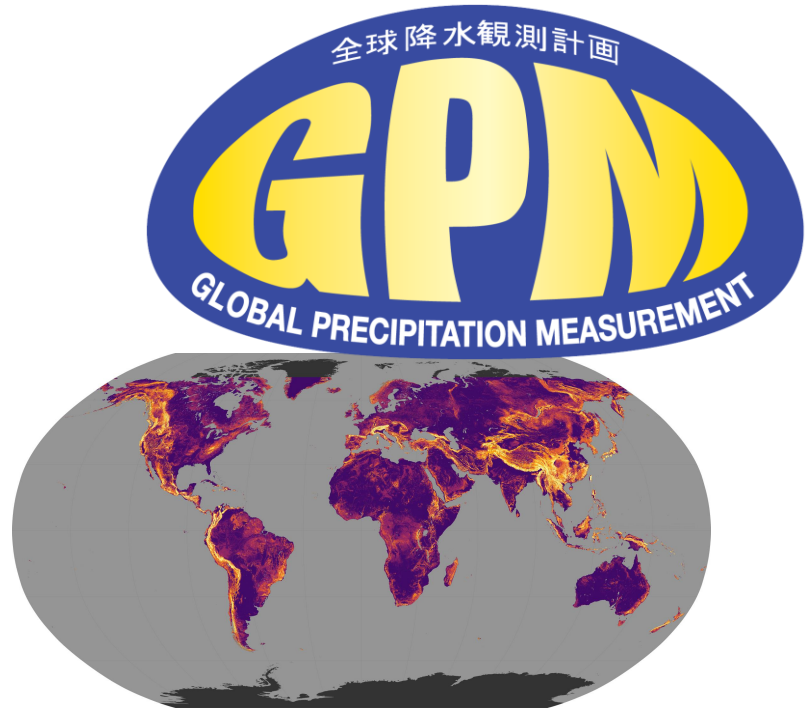


Version 2.0

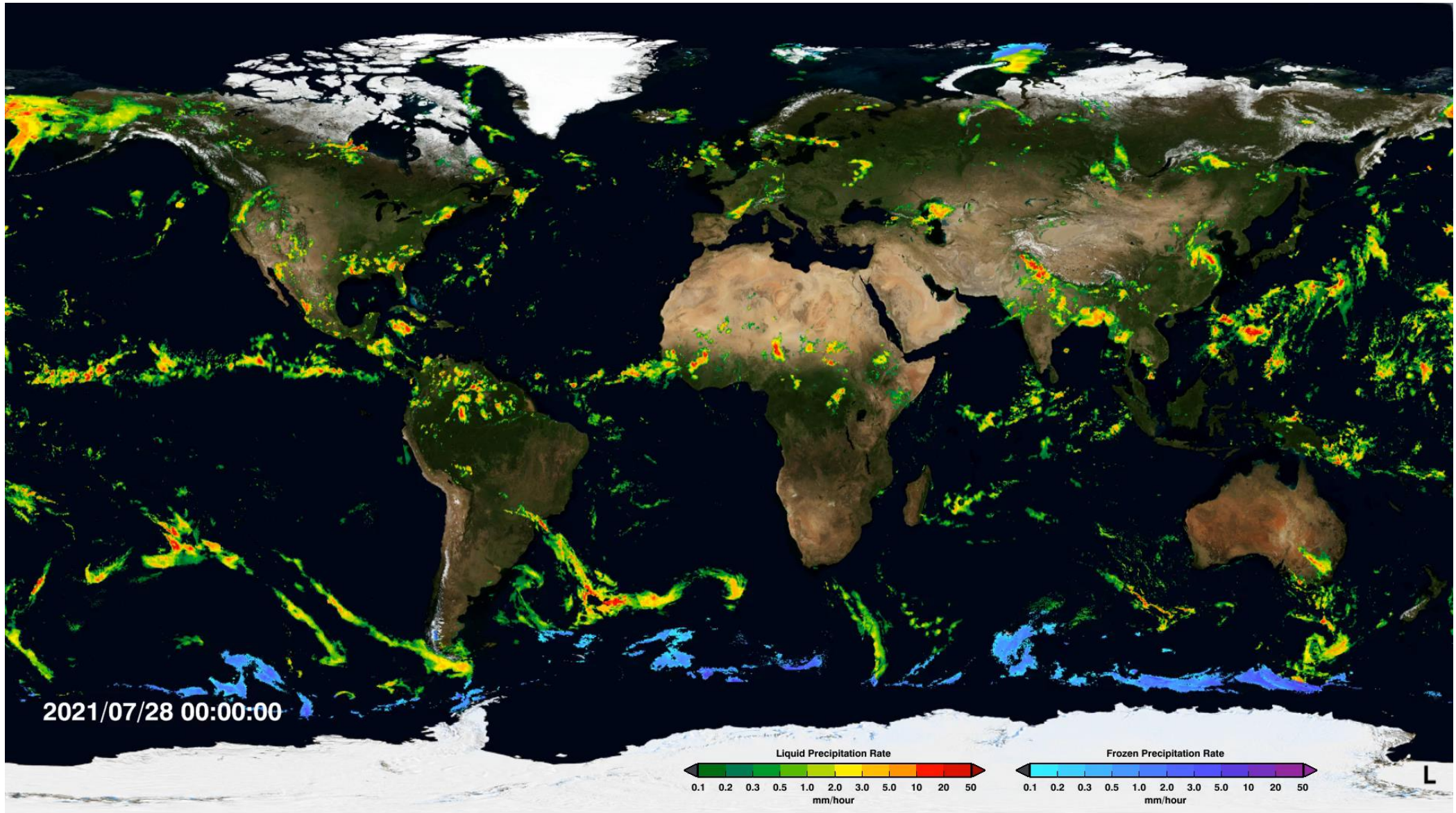


The Landslide Hazard Assessment for Situational Awareness (LHASA) Model

Version 1.1

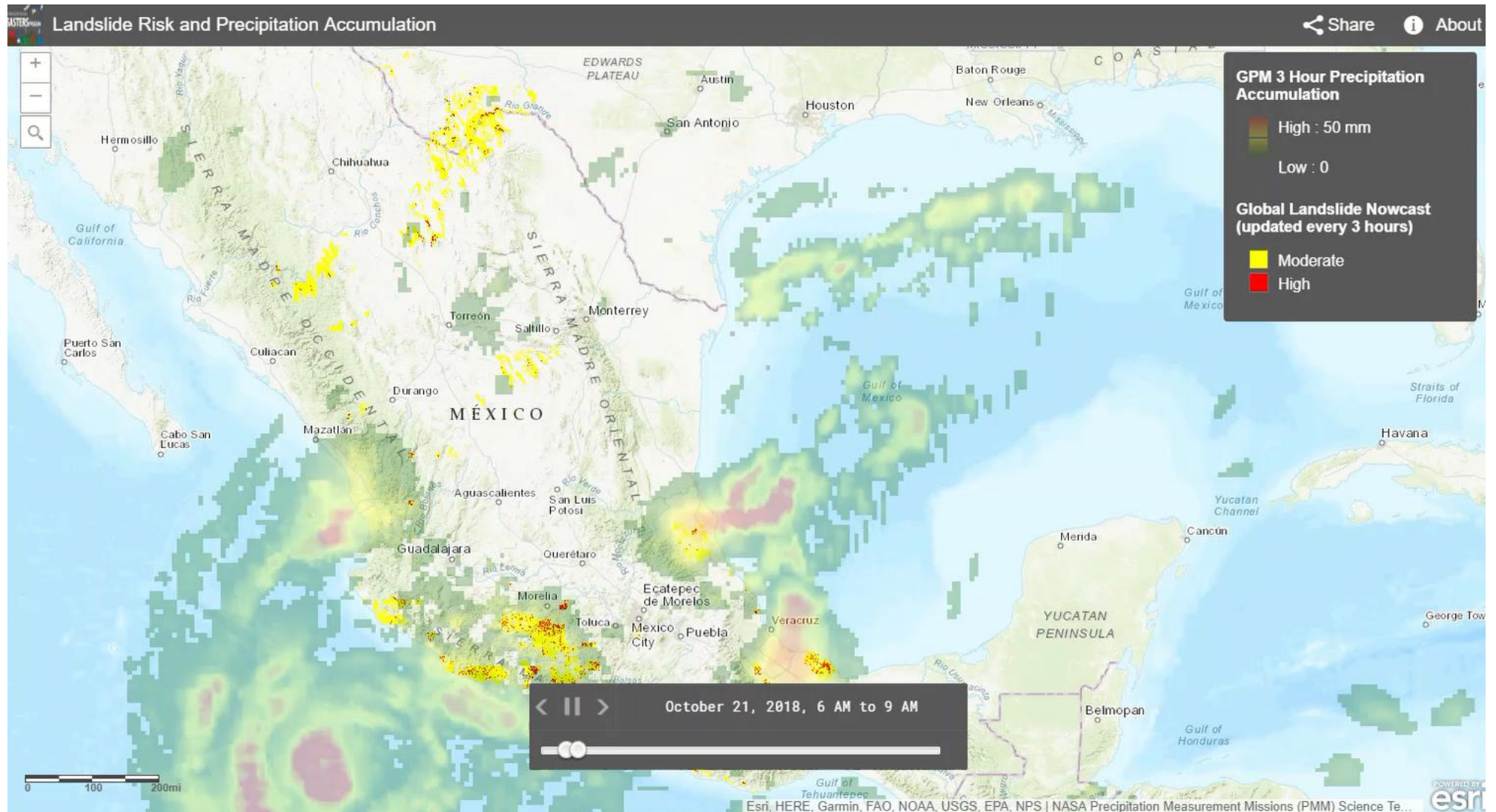


IMERG: Integrated Multi-satellite Retrievals for GPM



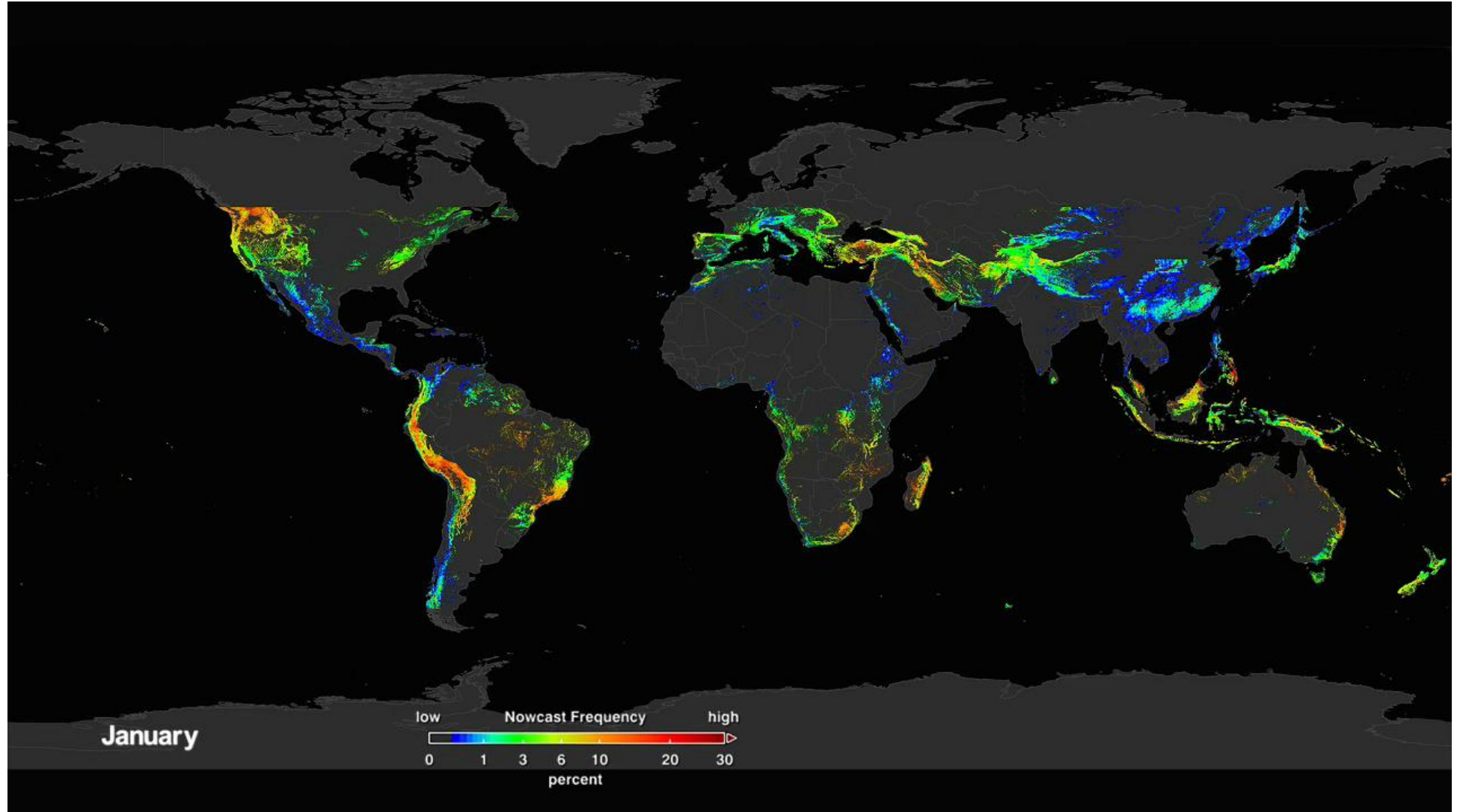
LHASA Output for Hurricane Willa, 2018

Version 1.1



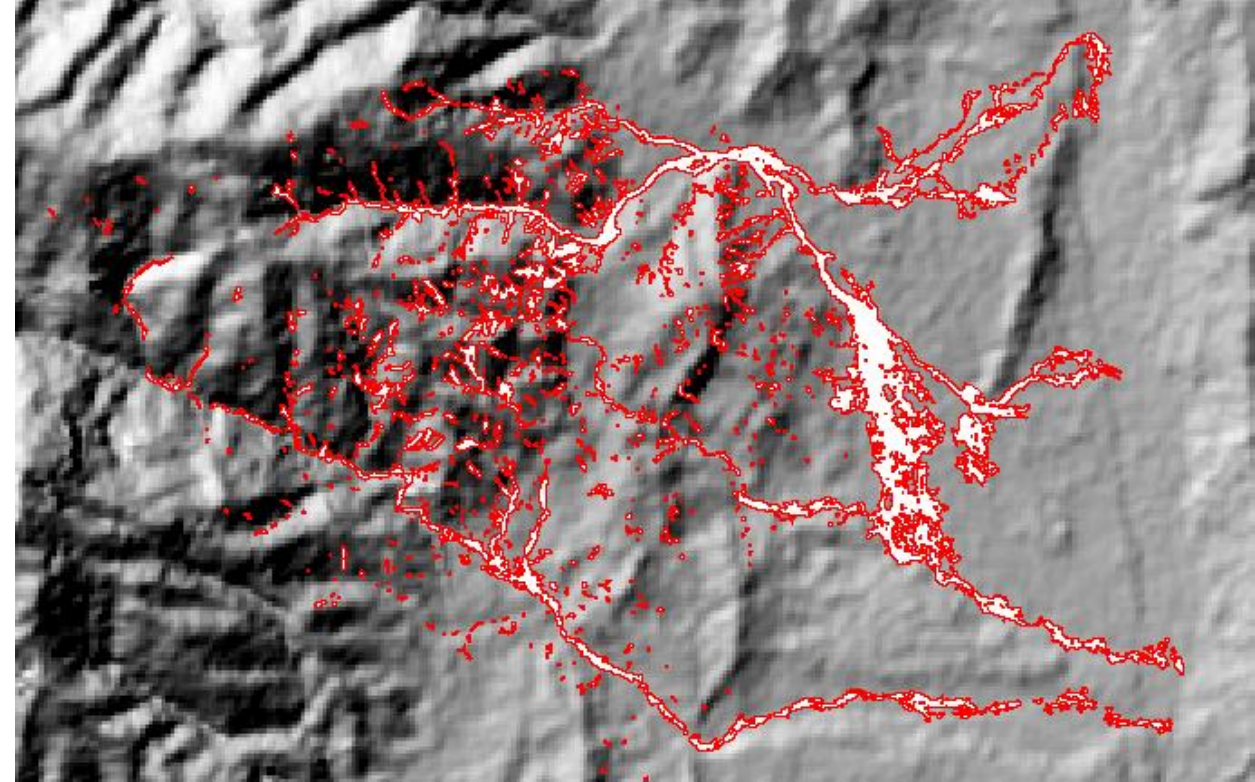
The Landslide Hazard Assessment for Situational Awareness (LHASA) Model

Version 1.1



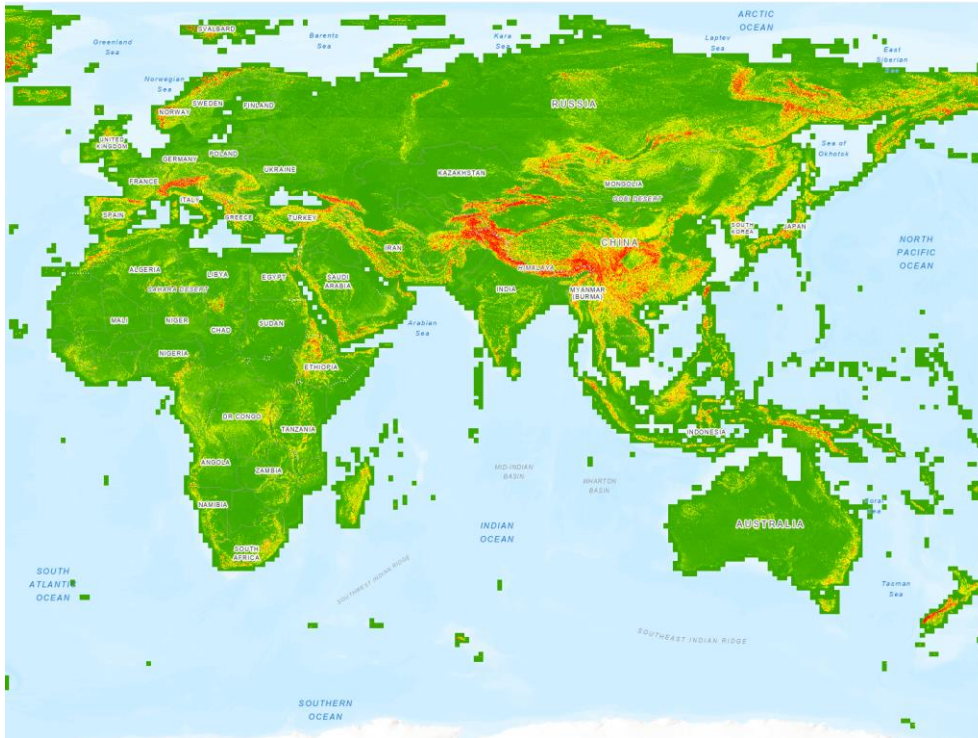
The Landslide Hazard Assessment for Situational Awareness (LHASA) Model

Version 2.0



The Landslide Hazard Assessment for Situational Awareness (LHASA) Model

Version 2.0



Slope Gradient

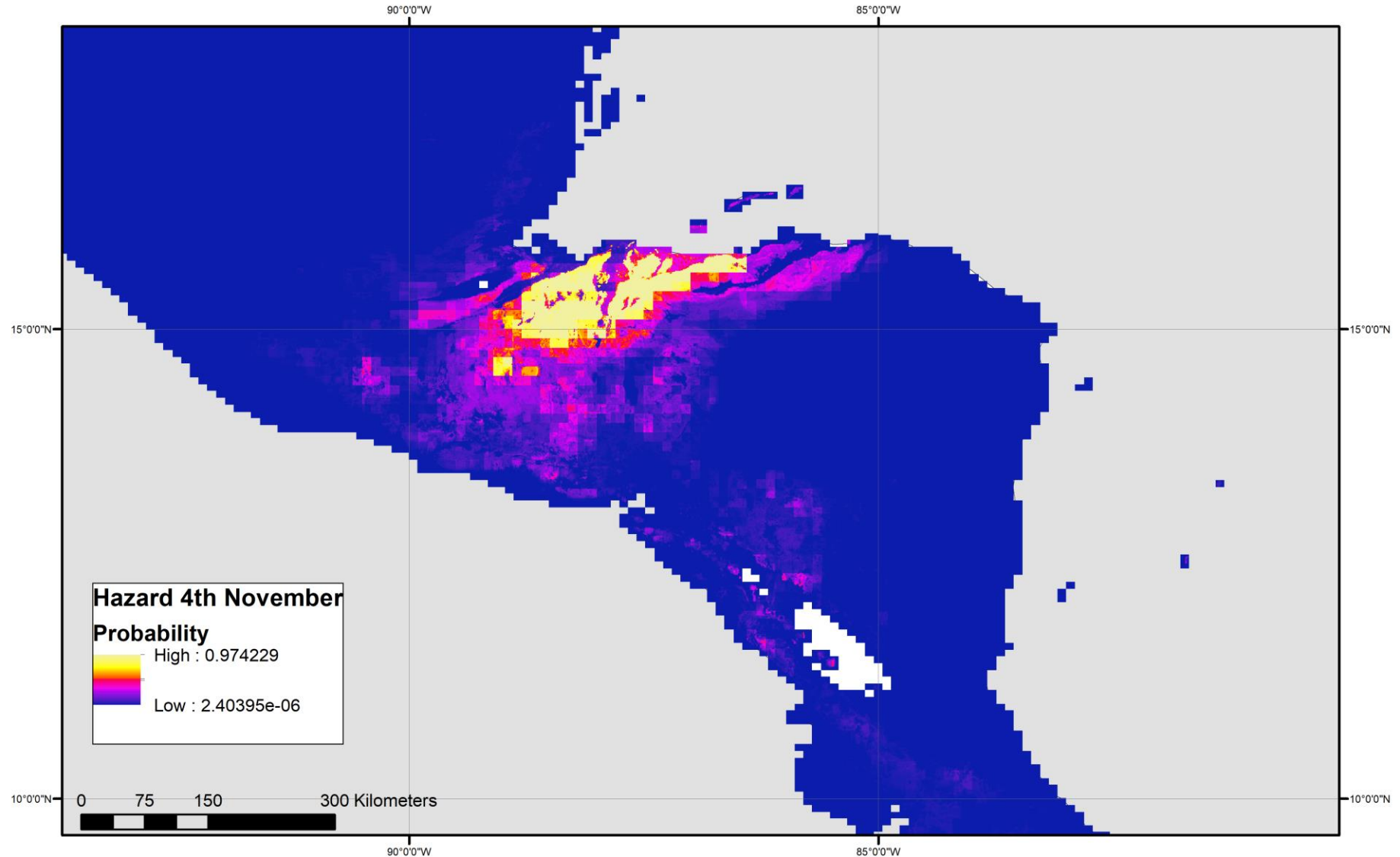


Distance to Fault



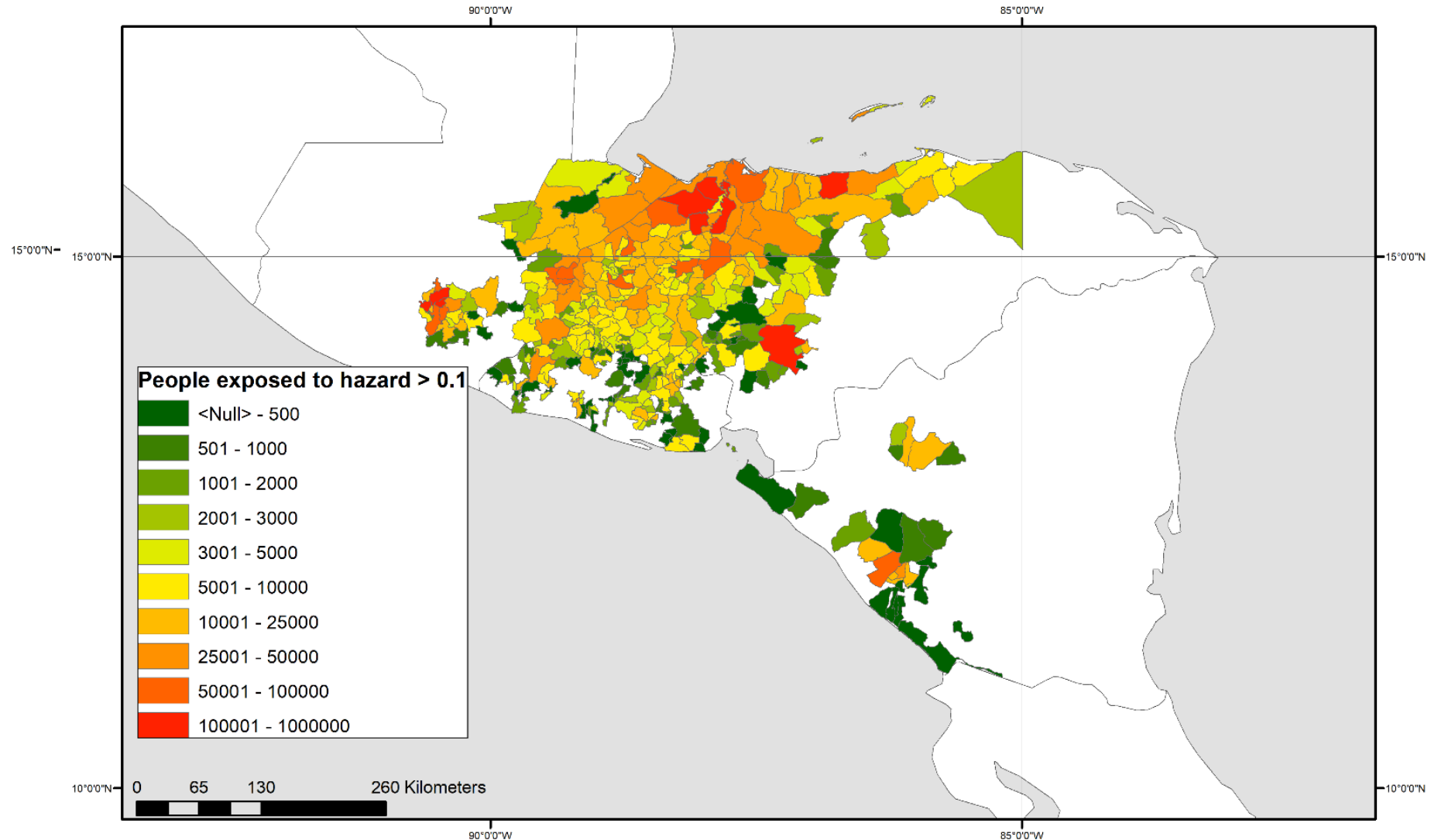
The Landslide Hazard Assessment for Situational Awareness (LHASA) Model

Version 2.0



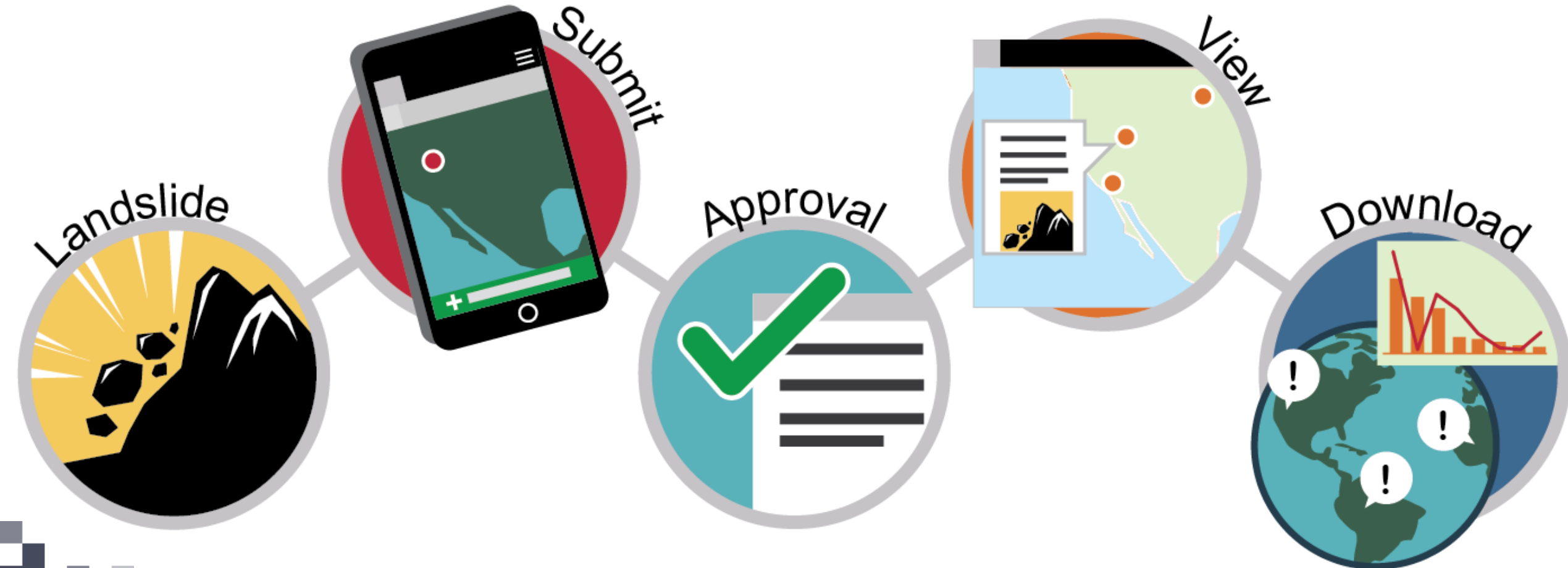
The Landslide Hazard Assessment for Situational Awareness (LHASA) Model

Version 2.0



Reporting Landslides During or After an Event

At Landslide Reporter (landslides.nasa.gov/reporter)



Why report landslides?



At Landslide Reporter (landslides.nasa.gov/reporter)

Benefits to Science:

- We use this data to evaluate the nowcast and other models.
- Helps to quantify the impacts of landslides, which are currently underreported
- Fills in the gaps in our knowledge due to reporting biases in other landslide inventories like the GLC
 - This might lead to a fairer distribution of research and mitigation efforts to the locations that need it the most.

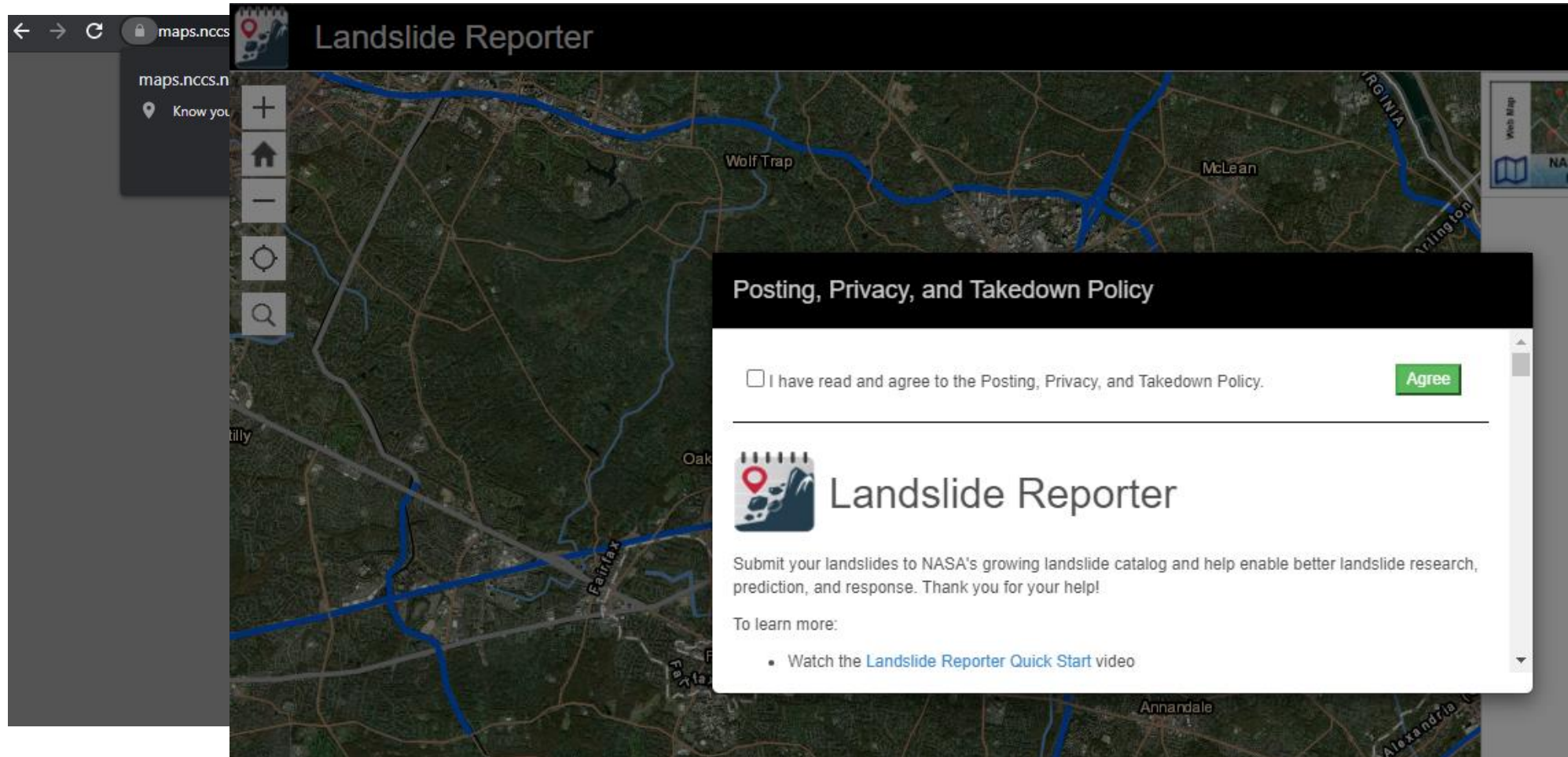
Benefits to Your Community:

- Brings global attention to your work on disaster risk reduction
- Can be a tool for educating citizens on landslide hazard
- Helps improve the accuracy of landslide models in your area
- Encourages data sharing by other stakeholders
- May provide the rationale for future funding requests
- You don't have to build your own app to do the same thing!



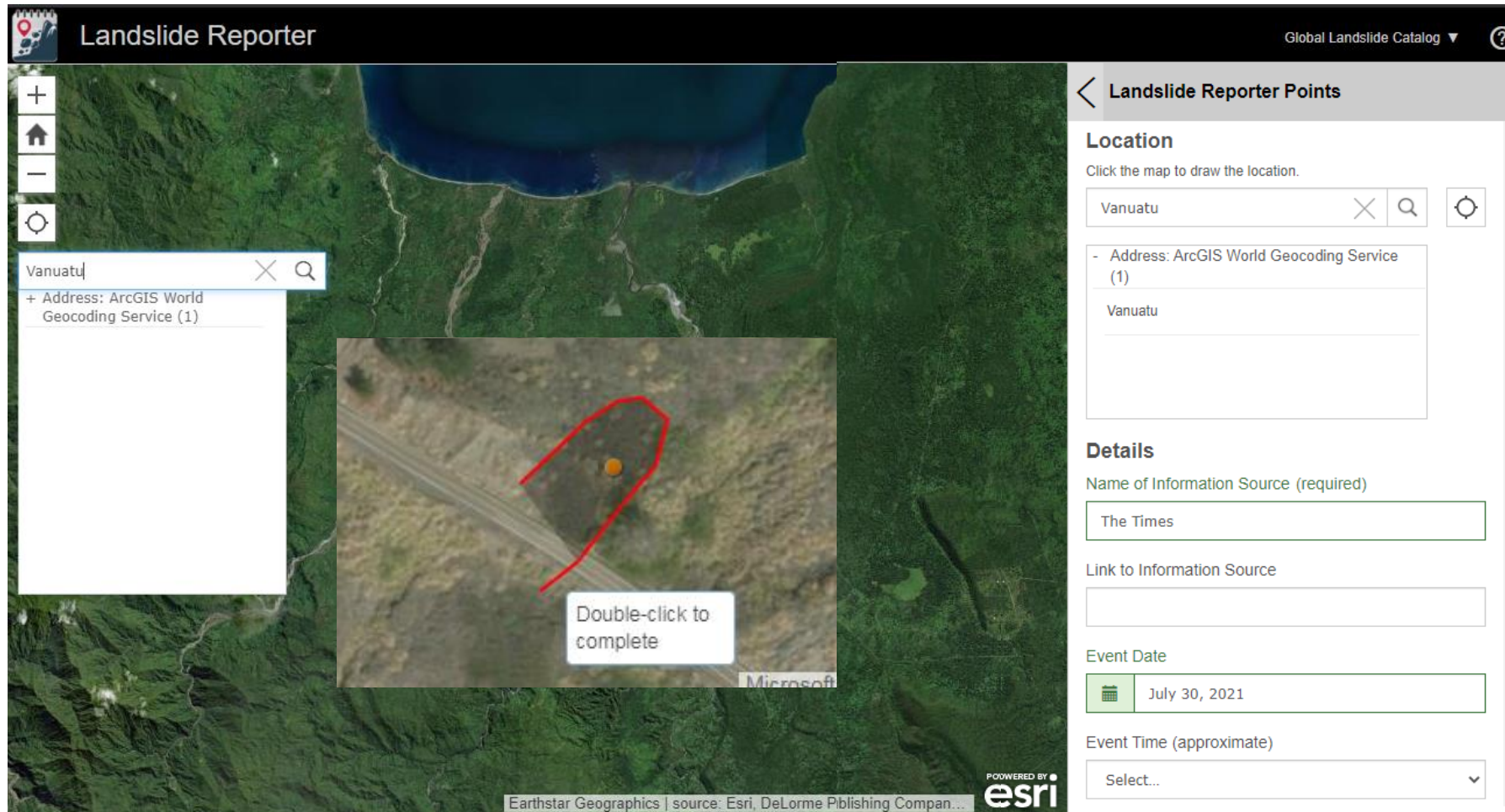
Reporting Landslides During or After an Event

At Landslide Reporter (landslides.nasa.gov/reporter)



Reporting Landslides During or After an Event

At Landslide Reporter (landslides.nasa.gov/reporter)



Landslide Reporter Global Landslide Catalog ?

Landslide Reporter Points

Location
Click the map to draw the location.

Vanuatu

- Address: ArcGIS World Geocoding Service (1)
Vanuatu

Details

Name of Information Source (required)
The Times

Link to Information Source

Event Date
July 30, 2021

Event Time (approximate)
Select...



Learning More about Landslide Reporter

At landslides.nasa.gov



LANDSLIDES @ NASA

[About](#) [How to Report](#) [Data](#) [Resources](#) [Policies](#)

[Reporter](#)

[Viewer](#)

Short Guides

This short 2-page guide will help you read the [how-to guides](#) below to scientists.

****Please note**, guides in other languages. These guides have not been cleaned accuracy of the translations.



Landslide Reporter

Very short introduction to contribute landslide data.

Volunteer Translations

- Arabic (العربية)
- Bengali (বাংলা)
- Czech (čeština)
- Gujarati (ગુજરાતી)
- Hindi (हिंदी)
- Italian (Italiano)

Landslide Reporter Quick Start

Click to add a point

Landslide Reporter

Quick Start

Watch on YouTube

Landslide Reporter Points

Event Date: June 06, 2010

Event Time (approximate): 01:00

Event Title: 276 between Island Ford Rd. and Conestee Trail

Event Description: A mudslide closed Highway 276 in Brevard, NC, as

Location Description:

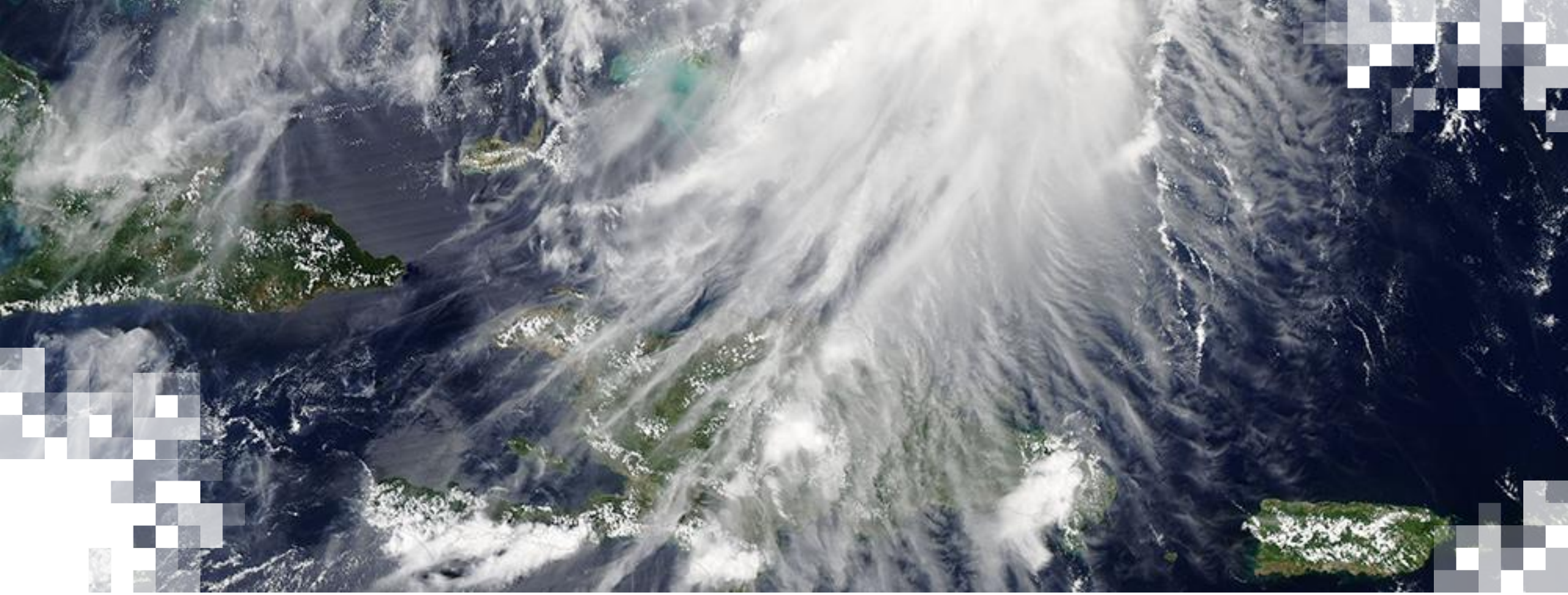
Location Accuracy: Known within 1 km

Landslide Category: Mudslide

Landslide Trigger: Champion

Estimated Size: Small



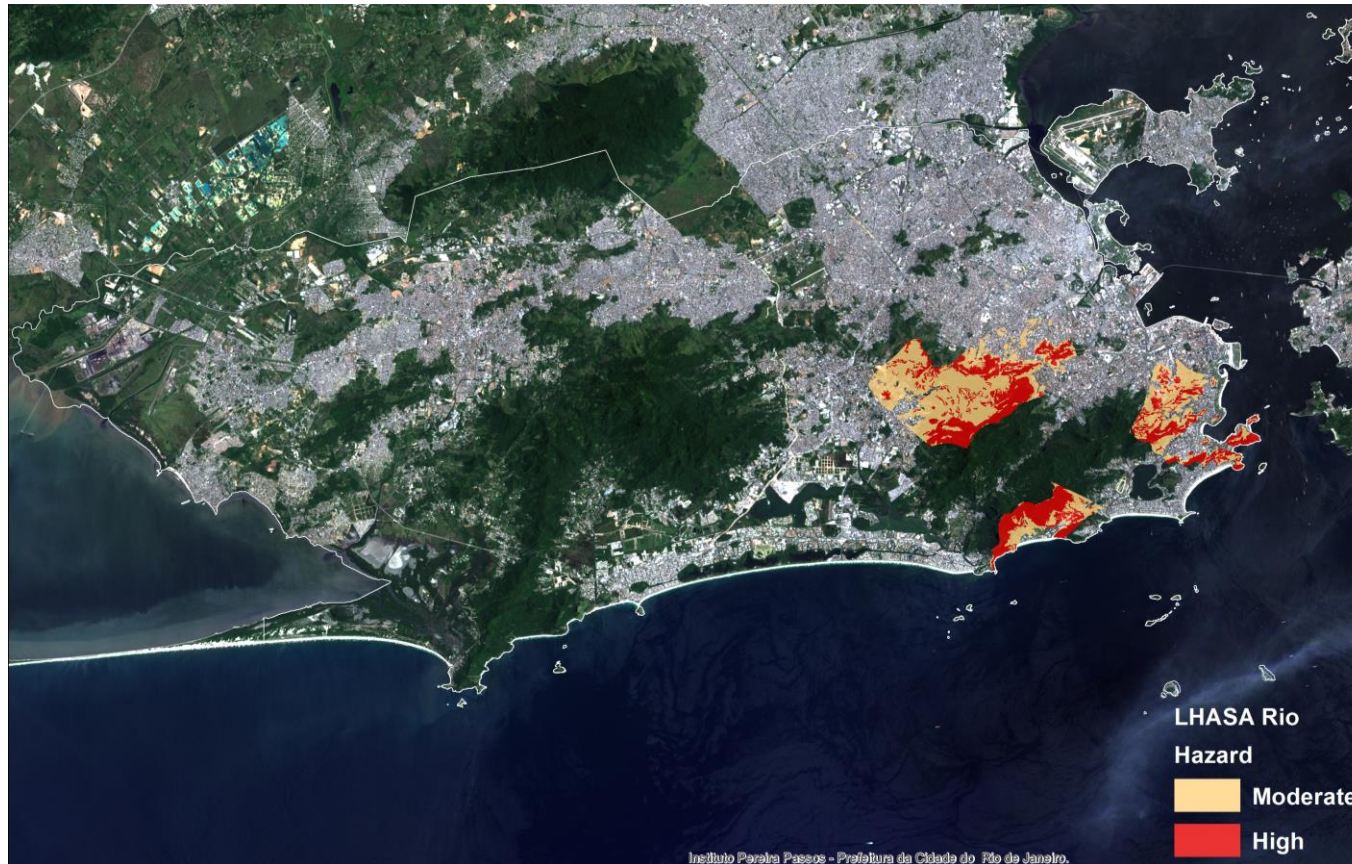


Rio de Janeiro Case Study

LHASA-Rio 1.0



LHASA-Rio 1.0



ALERTA RIO Sistema Alerta Rio da Prefeitura do Rio de Janeiro

Institucional | Alertas | Previsão do Tempo | Dados Meteorológicos | Radar Sumaré | App Alerta Rio | Estatísticas | Documentos | Notícias

Chuva fraca? Moderada? Forte?

Veja se está chovendo na estação do Alerta Rio mais próxima de você!

Confira

Tipos de nuvens

Entenda as diferenças entre elas!

Leia mais

Radar Meteorológico do Sumaré

Confira imagens atualizadas

Veja aqui

Chuva e Escorregamento

Situação do Município

Veja aqui

Baixe nossos dados!

Dados meteorológicos de 15 em 15 minutos!

Veja aqui

Previsão do Tempo

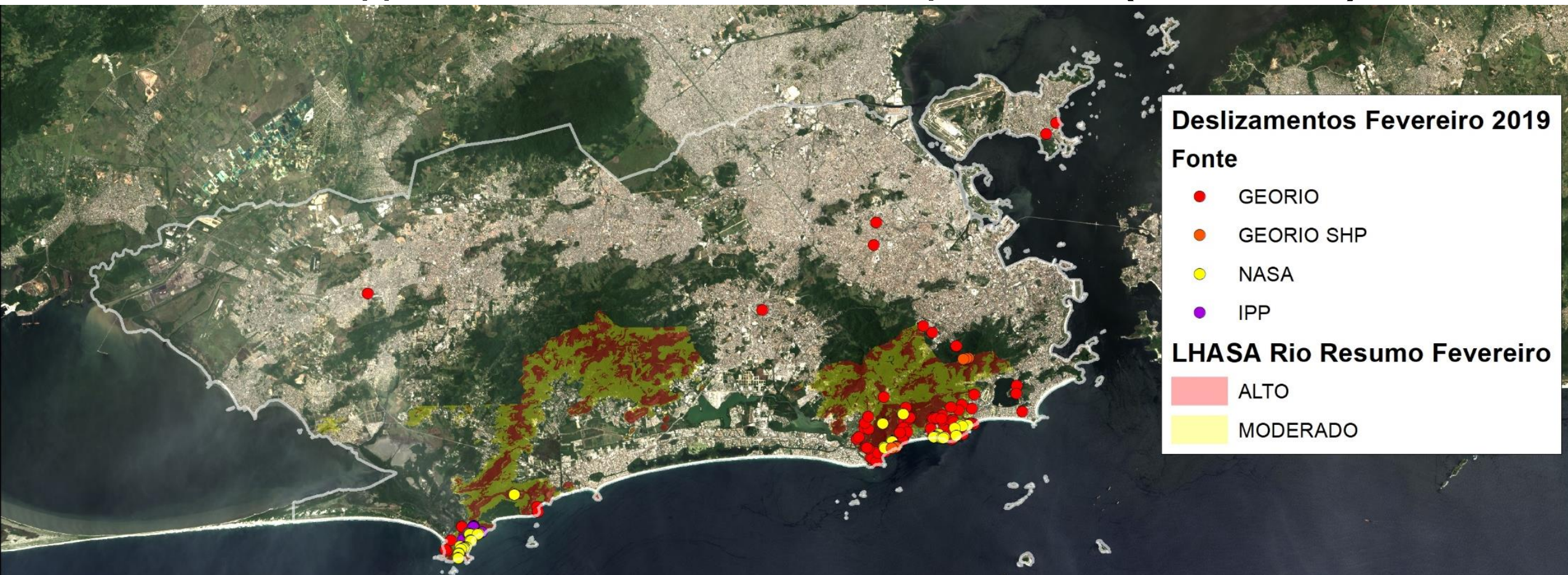
Próximas 24 horas no Rio de Janeiro

Veja aqui



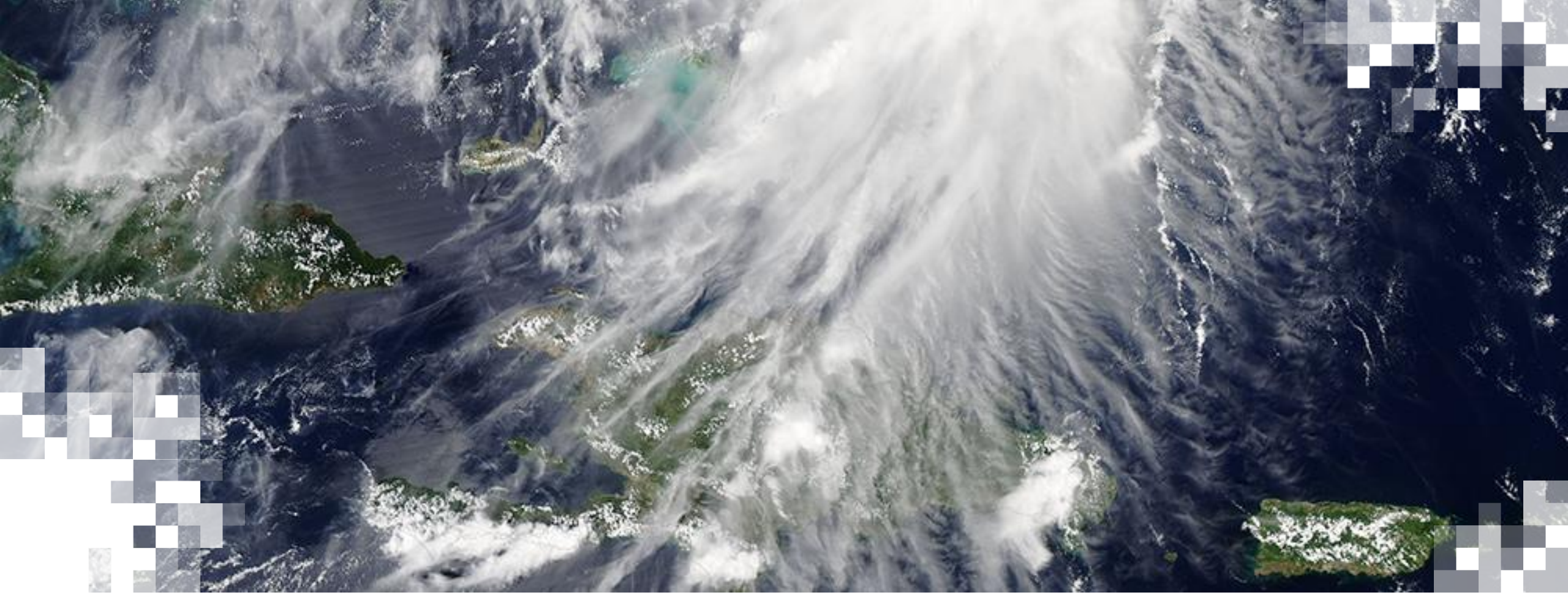
LHASA-Rio 1.0

169 landslides mapped, 156 hazard areas detected by LHASA Rio (92.3% hit rate).



Data Sources: LHASA Rio, Geo-Rio, NASA e IPP (imagens de alta resolução)
Slide courtesy of Felipe C. Mandarin, Rio de Janeiro

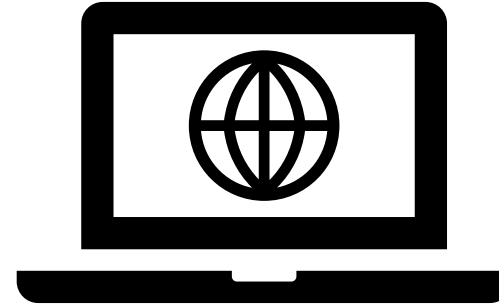




Getting Started with LHASA Version 1.1

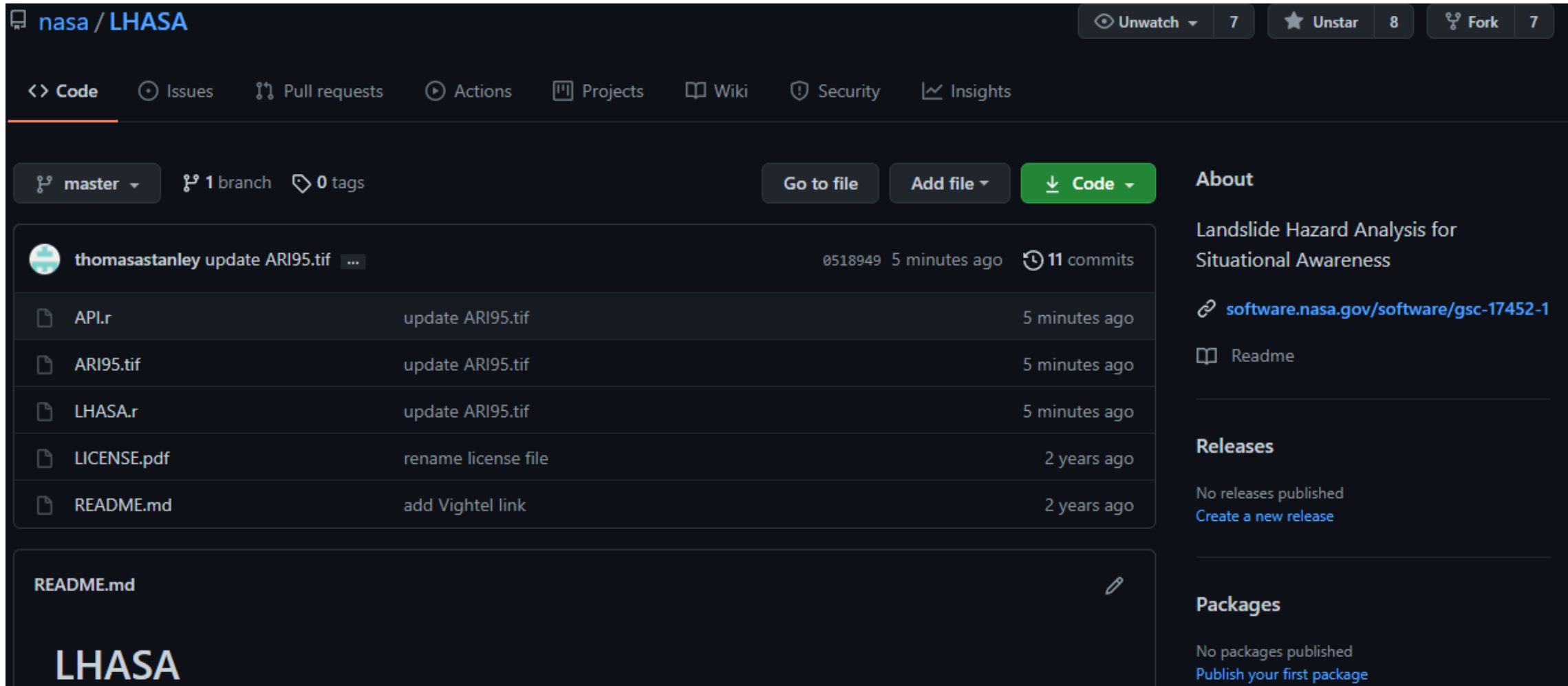
What You Need to Run LHASA Version 1.1

- A computer with the Windows operating system
 - (LHASA runs on other operating systems, but the appearance and key bindings are different from those shown here.)
- An internet connection
- R statistical software
 - Download at <https://cloud.r-project.org/>
 - (It's free of charge.)



Getting Started with LHASA Version 1.1

Step 1: Download the code from <https://github.com/nasa/LHASA>



The screenshot shows the GitHub repository page for `nasa / LHASA`. The repository is in the `master` branch, has 1 branch and 0 tags. It shows a commit history table with the following entries:

File	Commit Message	Time
API.r	update ARI95.tif	5 minutes ago
ARI95.tif	update ARI95.tif	5 minutes ago
LHASA.r	update ARI95.tif	5 minutes ago
LICENSE.pdf	rename license file	2 years ago
README.md	add VighTel link	2 years ago

The repository description is "Landslide Hazard Analysis for Situational Awareness". It includes a link to the software page: software.nasa.gov/software/gsc-17452-1 and a link to the README. The repository has 11 commits and no releases or packages published.

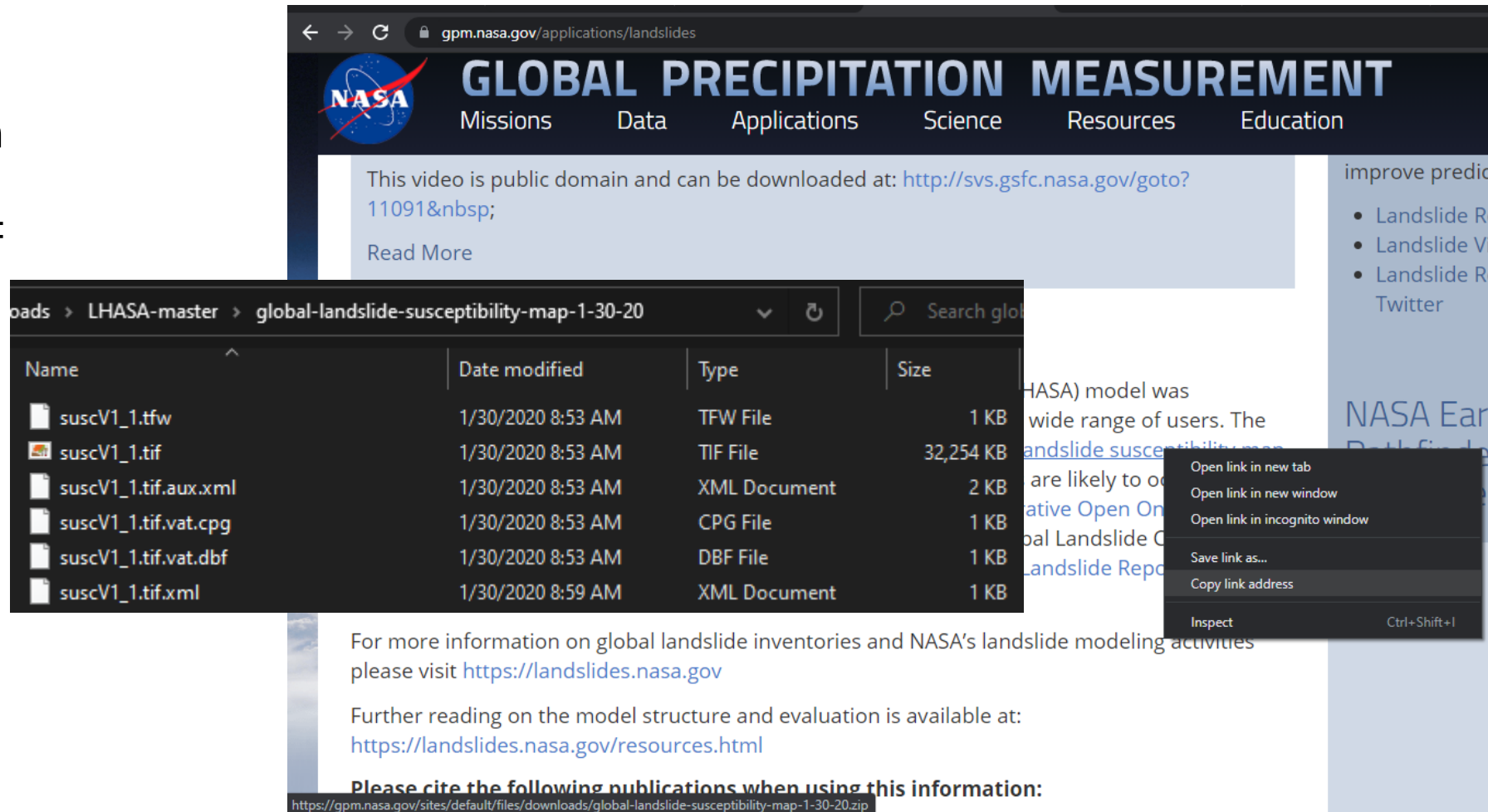


Getting Started with LHASA Version 1.1

Step 2: Download the global landslide susceptibility map from:

<https://gpm.nasa.gov/sites/default/files/downloads/global-landslide-susceptibility-map-1-30-20.zip>

Or use your own
susceptibility
map (in GeoTIFF
format)



gpm.nasa.gov/applications/landslides

GLOBAL PRECIPITATION MEASUREMENT

Missions Data Applications Science Resources Education

This video is public domain and can be downloaded at: <http://svs.gsfc.nasa.gov/goto?11091>;

Read More

improve predic

- Landslide Re
- Landslide Vi
- Landslide Re

Twitter

loads > LHASA-master > global-landslide-susceptibility-map-1-30-20

Name	Date modified	Type	Size
suscV1_1.tfw	1/30/2020 8:53 AM	TFW File	1 KB
suscV1_1.tif	1/30/2020 8:53 AM	TIF File	32,254 KB
suscV1_1.tif.aux.xml	1/30/2020 8:53 AM	XML Document	2 KB
suscV1_1.tif.vat.cpg	1/30/2020 8:53 AM	CPG File	1 KB
suscV1_1.tif.vat.dbf	1/30/2020 8:53 AM	DBF File	1 KB
suscV1_1.tif.xml	1/30/2020 8:59 AM	XML Document	1 KB

LHASA) model was
wide range of users. The
landslide suscep
are likely to oc
ative Open On
Global Landslide C
Landslide Repo

NASA Ear
Data File

Open link in new tab
Open link in new window
Open link in incognito window
Save link as...
Copy link address
Inspect Ctrl+Shift+I

For more information on global landslide inventories and NASA's landslide modeling activities
please visit <https://landslides.nasa.gov>

Further reading on the model structure and evaluation is available at:
<https://landslides.nasa.gov/resources.html>

Please cite the following publications when using this information:

<https://gpm.nasa.gov/sites/default/files/downloads/global-landslide-susceptibility-map-1-30-20.zip>



Getting Started with LHASA Version 1.1

Step 3: Download the IMERG data from <https://gpm.nasa.gov/data/IMERG>

1 Day IMERG Late Run Precipitation Accumulations in GeoTIFF format

- **Download URL:** <https://jsimpsonhttps.pps.eosdis.nasa.gov/IMERG/gis/>
- Longer latency than Early Run but a higher quality product.
- [Click here to register for the PPS FTP](#)
- [Read documentation for using IMERG GeoTIFF + Wordfiles](#)
- Files located in `./[yyyy]/[mm]`
- 30 minute, 3 hour, 1 day, 7 day, and 1 month files are all available in the same directory, with the timespan indicated within the filename (e.g. 3B-HHR-L.MS.MRG.3IMERG.20200516-S083000-E085959.0510.V06B.3hr.tif is a 3 hour file)
- 1 month files are located in the folder corresponding to the first day of each month.
- Precipitation values are scaled by a factor of x10 (0.1mm) for 30 minute, 3 hour, 1 day, 3 day and 7 day files, and are scaled by a factor of x1 (1mm) for 1 month files.

1 Day IMERG Late Run Precipitation Accumulations in GeoTIFF format

1 Month IMERG Final Run Precipitation Accumulations in GeoTIFF format



Getting Started with LHASA Version 1.1

Step 3a: Register with the NASA Precipitation Processing System (PPS)



PPS Registration

Click on "**Register**" to get access to PPS Products.

Fill out the form and click on "Save".

You will get a confirmation e-mail and use it to complete the process.

If you don't receive this e-mail in one hour, please check in your spam folder, and then contact helpdesk@mail.pps.eosdis.nasa.gov to resolve the issue.

Once you are registered, you can edit your information by entering in your email address (below) and clicking on "Verify Email or Update Info". Please follow the instructions contained in the automated email to complete the process.

Please note that by registering to get access to GPM data through PPS, you are also agreeing to receive emails from PPS informing you of system and product status. If you do not wish to receive system status emails then please do not register for access to PPS.

We do not accept email addresses that require us to take a manual action (Boxbe, etc.). Please do not use a university address that is a reflector to gmail but use the direct gmail address instead.

If you plan to use Near-Real Time (NRT) data stored on jsimpsonftp.pps.eosdis.nasa.gov, make sure to check the box stating that you are interested in NRT products. Otherwise, your account will only allow access to production data on arthurhou.pps.eosdis.nasa.gov. However, if you do not need to use NRT products, please do not register for NRT access. You can add/remove NRT access using the "Verify Email or Update Info" tool.

Please note that your Email will be converted to lower case. Once registration is completed use this email address in lower case as both your User Name and Password to retrieve data from our FTP archives or place orders through STORM.

NEVER reply to an email that is sent to you. If you have questions, please contact helpdesk@mail.pps.eosdis.nasa.gov.

Register

OR

Enter registered email:

Verify Email or Update Info

Remove from access to PPS

<https://registration.pps.eosdis.nasa.gov/registration/>

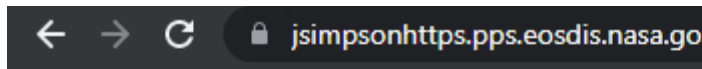


Getting Started with LHASA Version 1.1

Step 3b: Download IMERG



Index of /imerg/gis/2004/08



Name	Last modified	Size	Description
------	---------------	------	-------------

Parent Directory	-	-	-
01/	2019-08-22 15:50	-	-
02/	2019-08-22 16:03	-	-
03/	2019-08-22 16:34	-	-
04/	2019-08-22 16:46	-	-
05/	2019-08-22 17:08	-	-
06/	2019-08-22 17:21	-	-
07/	2019-08-22 17:37	-	-

Name	Last modified	Size	Description
------	---------------	------	-------------

Parent Directory	-	-	-
3B-DAY-L.GIS.IMERG.2..>	2019-08-18 17:44	6.4M	-
3B-DAY-L.GIS.IMERG.2..>	2019-08-18 17:47	6.4M	-
3B-DAY-L.GIS.IMERG.2..>	2019-08-18 17:50	6.7M	-
3B-DAY-L.GIS.IMERG.2..>	2019-08-18 17:53	6.8M	-
3B-DAY-L.GIS.IMERG.2..>	2019-08-18 17:56	6.7M	-
3B-DAY-L.GIS.IMERG.2..>	2019-08-18 17:59	6.5M	-
3B-DAY-L.GIS.IMERG.2..>	2019-08-18 18:02	6.6M	-

- 10/
- 11/
- 12/
- 2000/
- 2001/
- 2002/
- 2003/
- 2004/
- 2005/
- 2006/

File name: 3B-DAY-L.GIS.IMERG.20040801.V06B.zip

Save as type: Compressed (zipped) Folder (*.zip)

Save Cancel

3B-DAY-L.GIS.IMERG.2..>	2019-08-18 18:20	6.5M	-
3B-DAY-L.GIS.IMERG.2..>	2019-08-18 18:23	6.7M	-
3B-DAY-L.GIS.IMERG.2..>	2019-08-18 18:26	6.6M	-
3B-DAY-L.GIS.IMERG.2..>	2019-08-18 18:29	6.6M	-



Getting Started with LHASA Version 1.1

Step 3c: Extract rainfall data files

The screenshot displays a Windows File Explorer window with the address bar showing the path: `C:\Downloads\LHASA-master\IMERG\3B-DAY-L.GIS.IMERG.20040801.V06B.zip`. The window title is `3B-DAY-L.GIS.IMERG.20040801.V06B.zip`. The `Extract` tab is active, showing a list of files to be extracted. The files are as follows:

Name	Type
3B-DAY-L.GIS.IMERG.20040801.V06B.ice.tfw	TFW File
3B-DAY-L.GIS.IMERG.20040801.V06B.ice.tif	TIF File
3B-DAY-L.GIS.IMERG.20040801.V06B.liquid.tfw	TFW File
3B-DAY-L.GIS.IMERG.20040801.V06B.liquid.tif	TIF File
3B-DAY-L.GIS.IMERG.20040801.V06B.liquidPercent.tfw	TFW File
3B-DAY-L.GIS.IMERG.20040801.V06B.liquidPercent.tif	TIF File
3B-DAY-L.GIS.IMERG.20040801.V06B.tfw	TFW File
3B-DAY-L.GIS.IMERG.20040801.V06B.tif	TIF File
DOI.txt	Text Document

Below the main window, a smaller window shows the contents of the `IMERG` folder, which includes the extracted files and the original zip file:

Name	Date modified	Type	Size
3B-DAY-L.GIS.IMERG.20040801.V06B.liquid.tif	8/18/2019 1:44 PM	TIF File	2,979 KB
3B-DAY-L.GIS.IMERG.20040801.V06B.zip	8/1/2021 9:21 PM	Compressed (zipp...	6,509 KB



Getting Started with LHASA Version 1.1

Step 4: Calculate the Antecedent Rainfall Index

RGui (64-bit) - [C:\Users\tastanle\Downloads\LHASA-master\API.r - R Editor]

File Edit Packages Windows Help



```
# 7-day ARI calculation v1.1.1
```

```
# 2021-8-2
```

```
# Thomas Stanley NASA
```

```
# Calculates a 7-day
```

```
# Load R packages
```

```
library(raster)
```

```
# Set working directory
```

```
setwd('C:/LHASA')
```

```
files <- list.files(p
```

```
# Set antecedent rain
```

```
ARI.window <- 7
```

```
# Set IDW exponent
```

```
exponent <- 2
```

```
# Calculate weights
```

```
w <- 1/seq(ARI.window, 1)^exponent
```

```
# Iterate through every day, starting at the end of the 1st ARI window
```

```
for(day in ARI.window:length(files)){
```

```
  # Open files within window, including current day
```

```
  IMERG <- crop(stack(files[(day - ARI.window + 1):day]), extent(-180, 180, -60, 60))
```

```
  # Calculate antecedent rainfall index
```

```
  ARI <- calc(w*IMERG, sum)/sum(w)
```

```
  # Save to disk
```

```
  writeRaster(ARI, filename=gsub('IMERG/', 'ARI/', files[day]))
```

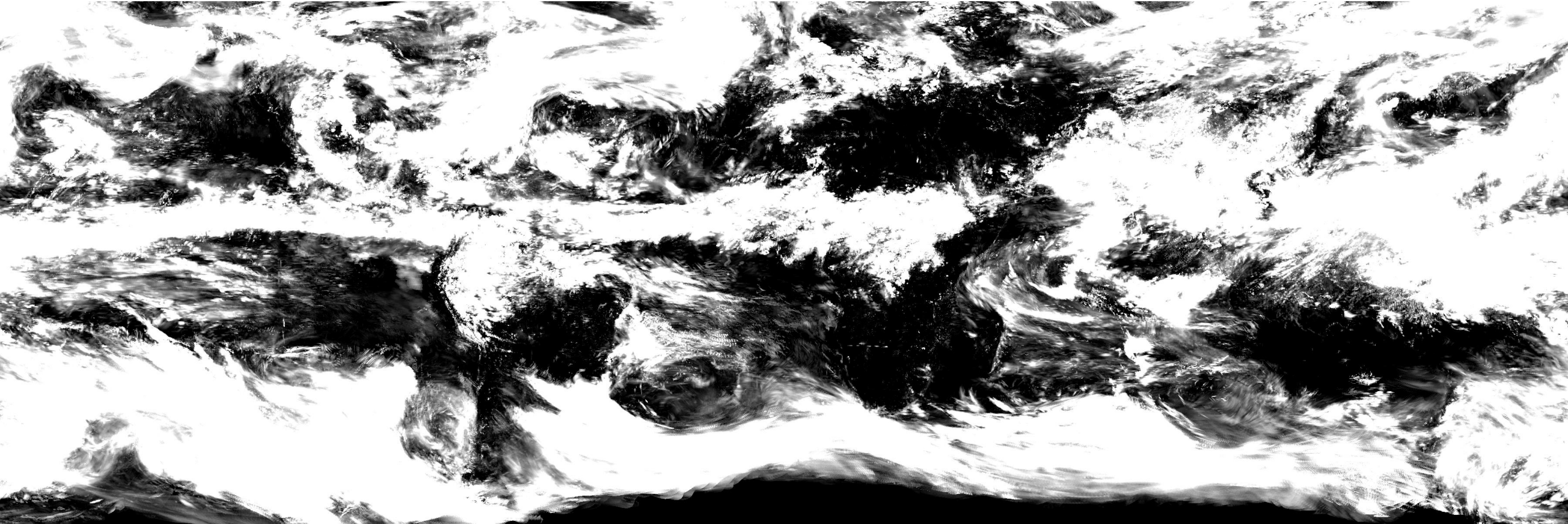
```
}
```

Name	Date modified	Type	Size
API	8/2/2021 10:53 AM	File folder	
global-landslide-susceptibility-map-1-30...	8/1/2021 4:42 PM	File folder	
IMERG	8/2/2021 10:34 AM	File folder	
API.r	1/12/2021 8:20 PM	R File	1 KB
ARI95.tif	1/12/2021 8:20 PM	TIF File	24,122 KB
LHASA.r	1/12/2021 8:20 PM	R File	2 KB
LICENSE.pdf	1/12/2021 8:20 PM	Adobe Acrobat D...	132 KB
README.md	1/12/2021 8:20 PM	MD File	1 KB



Getting Started with LHASA Version 1.1

Step 4: Calculate the Antecedent Rainfall Index



Getting Started with LHASA Version 1.1

Step 4: Run the LHASA model

RGui (64-bit) - [C:\Users\tastanle\Downloads\LHASA-master\LHASA.r - R Editor]

File Edit Packages Windows Help



```
# NASA Goddard Space Flight Center
# Maps the potential for landslides by identifying which locations
# exceed thresholds for a 7-day antecedent precipitation index
# and a landslide susceptibility map.

# Load packages
library(rgdal)
library(raster)
library(terra)

# Set working directory
setwd('C:/LHASA')

# Open antecedent rainfall threshold file
# Note that the version of this file posted at https://github.com/
# is based on the use of daily geotiff files, which are in tiff
# To use with the netcdf version of IMERG, divide by 10.
threshold <- crop(raster('ARI95.tif'), extent(-180, 180, -90, 90))

# Open the susceptibility map
susceptible <- crop(raster('global.tif'), extent(-180, 180, -90, 90))

files <- list.files(path='ARI', pattern='*.tif', full.names=T)

# Iterate through all days in record
for(f in files){
  # Open antecedent rainfall index file for current date
  ARI <- raster(f)
  # Compare to ARI threshold
  wet <- ARI > threshold
  # Run decision tree model at resolution of susceptibility map
  moderate <- resample(wet, susceptible, method='ngb') & (susceptible > 2)
  high <- moderate & (susceptible > 4)

  # Save outputs
  writeRaster(nowcast, filename=gsub('ARI/', 'nowcast/', f), datatype='INT1U')
}
```

C > Downloads > LHASA-master			
Search LHASA-master			
Name	Date modified	Type	Size
ARI	8/2/2021 10:02 PM	File folder	
IMERG	8/2/2021 5:23 PM	File folder	
nowcast	8/2/2021 10:02 PM	File folder	
API.r	8/2/2021 10:01 PM	R File	1 KB
ARI95.tif	8/2/2021 10:01 PM	TIF File	23,234 KB
global.tif	8/2/2021 4:44 PM	TIF File	32,583 KB
LHASA.r	8/2/2021 10:01 PM	R File	2 KB
LICENSE.pdf	8/2/2021 10:01 PM	Adobe Acrobat D...	132 KB
README.md	8/2/2021 10:01 PM	MD File	1 KB



Getting Started with LHASA Version 1.1

Step 4: Run the LHASA model

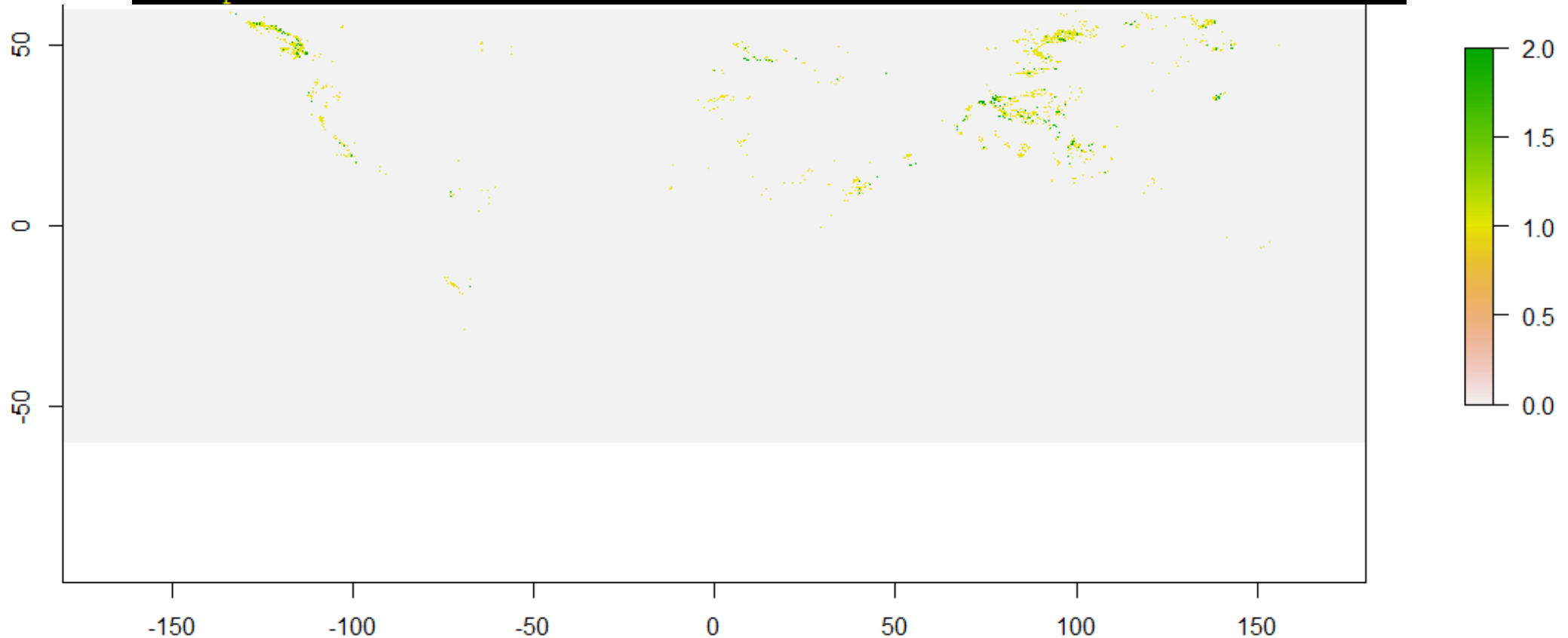
```
> # Landslide Hazard Assessment for Situational Awareness, version 1.1.1
> # By Thomas Stanley USRA/GESTAR 2021-8-2
> # NASA Goddard Space Flight Center
> # Maps the potential for landslides by identifying which locations
> # exceed thresholds for a 7-day antecedent precipitation index
> # and a landslide susceptibility map.
>
> # Load packages
> library(raster)
> # Set working directory
> setwd('C:/Users/tastanle/Downloads/LHASA-master')
>
> # Open antecedent rainfall threshold file
> # Note that the version of this file posted at https://github.com/nasa/LHASA
> # is based on the use of daily geotiff files, which are in tenths of mm.
> # To use with the netcdf version of IMERG, divide by 10.
> threshold <- crop(raster('ARI95.tif'), extent(-180, 180, -60, 60))
> # Open the susceptibility map
> susceptible <- crop(raster('global.tif'), extent(-180, 180, -60, 60))
```



Getting Started with LHASA Version 1.1

Step 5: View the Nowcast

```
> for(f in files){  
+ # Open antecedent rainfall index file for current date
```



Next Steps with LHASA Version 1.1

How to make it work better for your island:

1. Evaluate the model's historic performance
 - Did it predict most landslides?
 - Was there a type of landslide or rainstorm it didn't do well on?
 - Is there a part of the island for which it's more accurate?
2. Raise or lower the rainfall threshold or susceptibility threshold
3. Replace the global susceptibility map with a national one
4. Replace IMERG with a high-resolution rainfall dataset from radar, gauges, or models



Review

Assessing Landslide Hazard on Small Island Nations

- Information on landslides can be useful at all stages of the disaster life cycle.
- NASA has several online resources:
 - At Landslide Viewer
 - At Landslide Reporter
- The LHASA model uses IMERG precipitation to produce global landslide nowcasts.
- You can implement LHASA version 1.1 with open-source code and open data.
 - But customizing it for your region is recommended.



References

- Stanley, T. A., D. B. Kirschbaum, G. Benz, et al. 2021. "Data-Driven Landslide Nowcasting at the Global Scale." *Frontiers in Earth Science*, 9: [10.3389/feart.2021.640043]
- Emberson, R., D. Kirschbaum, and T. Stanley. 2021. "Global connections between El Nino and landslide impacts." *Nature Communications*, 12 (1): 2262 [10.1038/s41467-021-22398-4]
- Emberson, R., D. Kirschbaum, and T. Stanley. 2020. "New global characterisation of landslide exposure." *Natural Hazards and Earth System Sciences*, 20 (12): 3413-3424 [10.5194/nhess-20-3413-2020]
- Juang, C. S., T. A. Stanley, and D. B. Kirschbaum. 2019. "Using citizen science to expand the global map of landslides: Introducing the Cooperative Open Online Landslide Repository (COOLR)." *PLOS ONE*, 14 (7): e0218657 [10.1371/journal.pone.0218657]
- Kirschbaum, D., and T. Stanley. 2018. "Satellite-Based Assessment of Rainfall-Triggered Landslide Hazard for Situational Awareness." *Earth's Future*, 6 (3): 505-523 [10.1002/2017ef000715]
- Stanley, T., and D. B. Kirschbaum. 2017. "A heuristic approach to global landslide susceptibility mapping." *Natural Hazards*, 1-20 [10.1007/s11069-017-2757-y]
- Kirschbaum, D. B., T. Stanley, and Y. Zhou. 2015. "Spatial and temporal analysis of a global landslide catalog." *Geomorphology*, 249 (Geohazard Databases): 4-15 [10.1016/j.geomorph.2015.03.016]
- Kirschbaum, D. B., R. F. Adler, Y. Hong, S. Hill, and A. Lerner-Lam. 2010. "A global landslide catalog for hazard applications: method, results, and limitations." *Natural Hazards* 52 (3): 561-575 [10.1007/s11069-009-9401-4]



Homework and Certificate

- One homework assignment:
 - Answers must be submitted via Google Form, accessed from the ARSET [website](#).
 - Homework will be made available on August 26th.
 - Due date for homework: September 15, 2021
- A certificate of completion will be awarded to those who:
 - Attend all live webinars
 - Complete the homework assignment by the deadline
 - You will receive a certificate approximately two months after the completion of the course from: marines.martins@ssaihq.com



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Follow us on Twitter
[@NASAARSET](https://twitter.com/NASAARSET)

Training Webpage:

- <https://appliedsciences.nasa.gov/join-mission/training/english/arset-satellite-observations-analyzing-natural-hazards-small-island>

ARSET Website:

- <https://appliedsciences.nasa.gov/what-we-do/capacity-building/arset>



Questions

- Please enter your questions in the Q&A box. We will answer them in the order they were received.
- We will post the Q&A to the training website following the conclusion of the webinar.

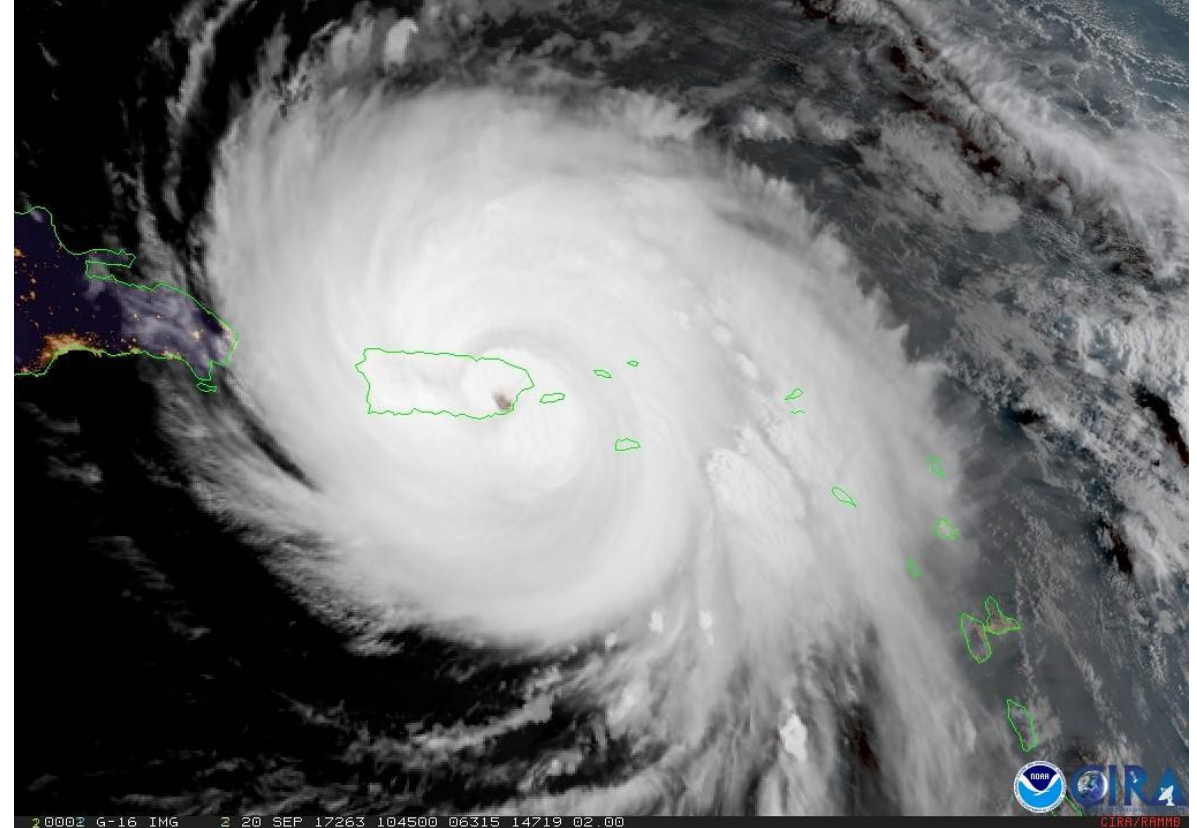


Image Credit: [NOAA](#)



The materials in this presentation draw on work by:

James Shute, Ryan Forbes, Neh Patel, Laura Carriere, Caroline Juang, Dalia Kirschbaum, Jack Simmons, Robert Emberson, Pukar Amatya, Garrett Benz, Marin Clark, William Medwedeff, Yaping Zhou, George Huffman, and many, many more.



Thank You!

Computing and web portal provided by:

